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A TABULATION AND CLASSIFICATION OF THE STRUCTURES OF CLEAN SOLID SURFACES AND OF ADSORBED ATOMIC AND MOLECULAR MONOLAYERS AS DETERMINED FROM LOW ENERGY ELECTRON DIFFRACTION PATTERNS

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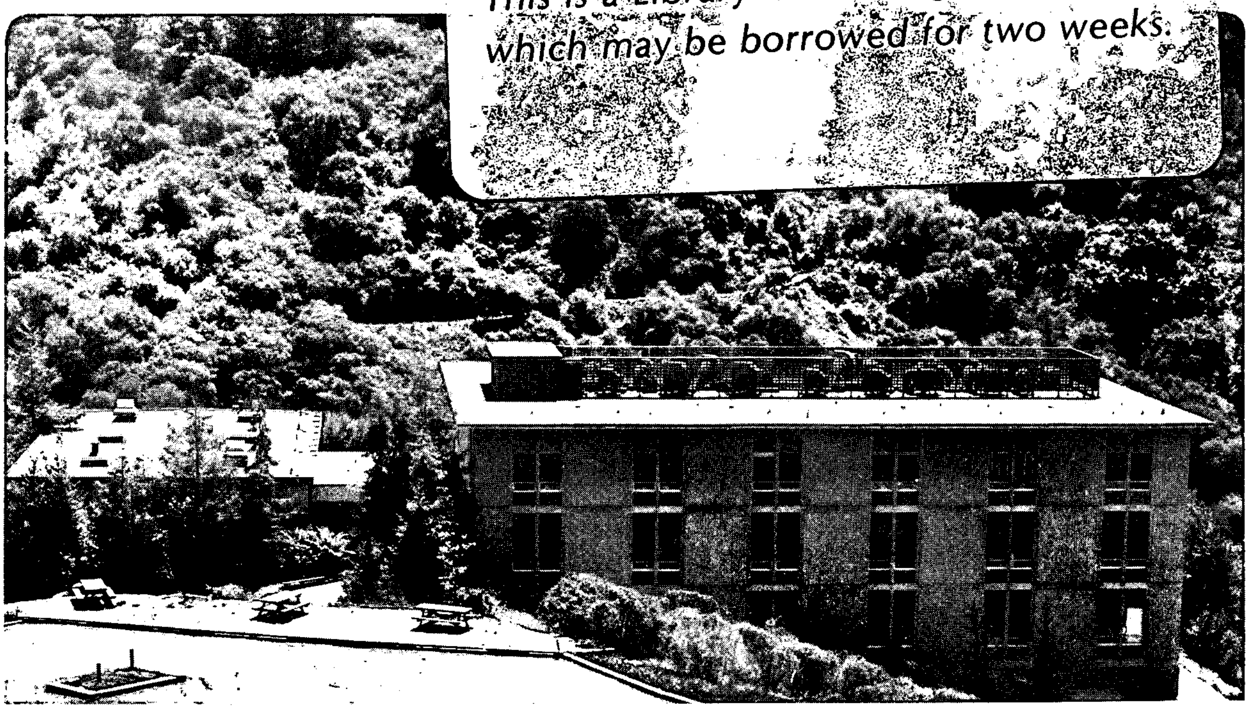

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A TABULATION AND CLASSIFICATION OF THE STRUCTURES OF CLEAN SOLID SURFACES AND OF ADSORBED ATOMIC AND MOLECULAR MONOLAYERS AS DETERMINED FROM LOW ENERGY ELECTRON DIFFRACTION PATTERNS

H. Ohtani, C.-T. Kao, M.A. Van Hove and G.A. Somorjai

Materials and Chemical Sciences Division,
Lawrence Berkeley Laboratory and Department of Chemistry,
University of California, Berkeley, California 94720

Abstract

A tabulation is presented of the ordering characteristics of clean and adsorbate-covered single crystal surfaces based on diffraction patterns observed with LEED (Low Energy Electron Diffraction). Over 3000 structures are classified by rotational symmetry of the substrate surfaces, and by important sub-classes which reflect recent directions of LEED studies. These include metallic monolayers, alloy surfaces, organic overlayers, coadsorbed overlayers, physisorbed overlayers, and high-Miller-index (stepped) surfaces. We review the important characteristics of each sub-class, and propose future directions of LEED investigations.

Contents

Abbreviations

AES	Auger Electron Spectroscopy
HEIS	High Energy Ion Scattering
HREELS	High Resolution Electron Energy Loss Spectroscopy
LEED	Low Energy Electron Diffraction
MEIS	Medium Energy Ion Scattering
SEXAFS	Surface Extended X-Ray Absorption Fine Structure
STM	Scanning Tunneling Microscopy
TDS	Thermal Desorption Spectroscopy
UPS	Ultraviolet Photoelectron Spectroscopy
XPS	X-Ray Photoelectron Spectroscopy

1. Introduction

During the last twenty-five years low energy electron diffraction (LEED) has provided the lion's share of information on the structure of clean single-crystal surfaces and of ordered atomic or molecular adsorbates on these surfaces. In most experiments the size and the orientation of the surface unit cell was determined under well-defined conditions of temperature and exposure to ambient gases to be adsorbed. The surfaces are first cleaned in ultra high vacuum by ion sputtering or by chemical means, the composition being monitored by electron or ion spectroscopies, then the surface structure is studied by LEED. Although methods of surface structure determination have been developed to obtain interatomic distances and angles, only the size and orientation of the surface unit cell is reported in most investigations. The reason for this is that the aim of the investigations has been the study of chemical or electronic properties of surfaces with less emphasis on the detailed atomic surface structure.

Reports of two-dimensional surface structures have rapidly accumulated in recent years. Somorjai and Szalkowski[1] listed over 200 surface structures in 1971 and extracted certain rules of ordering. In 1979 Castner and Somorjai[2] reported over 1000 surface structures. In addition, Bibérian and Somorjai[3] reviewed the surface structures of metallic monolayers on metal crystal surfaces; these represented a rapidly growing sub-class of monolayer structures.

This review updates and expands the surface structural data obtained for both clean and adsorbate-covered surfaces of single crystals: over 3000 surface structures are tabulated, most of which were studied in the last several years. These include clean and adsorbate-covered structures of single-crystal surfaces with high Miller indices and of polyatomic solids, as well as many simpler surface structures.

The available data indicate the predominance of ordering of clean solid surfaces and of adsorbed monolayers; however, these ordered surfaces only exist within a given range of temperature and coverage. It seems that there are always temperature and coverage ranges where ordered surfaces exist. There are many reconstructed surfaces and adsorbed monolayers which form both commensurate and incommensurate surface structures. A commensurate surface structure has a superlattice periodicity which is simply related to the substrate lattice periodicity, whereas an incommensurate surface structure has a superlattice periodicity independent of the substrate lattice periodicity. More accurate definitions of these terms and their physical implications will be given in Section 3.A and in Section 4.A, respectively.

Interesting trends of research can be identified from the data that have been reported in recent years. There is increased interest in investigations of alloy surfaces and of high Miller index (stepped) surfaces of metals. The studies of metal monolayers and organic overlayers are very rapidly growing directions of research. A large number of studies have focussed on inert gas adsorption and ordering, on the chemisorption of halogen atoms, especially chlorine, and on the coadsorption and ordering of two different adsorbates. On the other hand, there is a scarcity of surface structural information on polyatomic solids (oxides, sulfides, silicates carbonates, etc.). Also many important monatomic solids were not investigated by LEED, including boron, uranium, and manganese.

Reflecting these trends of LEED investigations, we have organized and classified the surface structural data in the following way. All the surface structures, except those formed by adsorption of organic molecules, are classified according to the rotational symmetry of the substrate surfaces when clean and unreconstructed; the surface structures formed on substrates with one-fold, two-fold, three-fold, and four-fold rotational symmetry are tabulated in Table I, II, III, and IV, respectively. The rotational symmetry of alloy surfaces is assumed to be the same as for the pure metal surfaces of the main component. This classification permits useful correlation of the various surface structures.

In addition, important subsets of the surface structures have been extracted and have been gathered in Tables V–X in order to clarify the characteristic trends in these areas. The surface structures of metallic monolayers on metal crystal surfaces and the alloy surface structures are collected in Tables V and VI, respectively. We highlight the surface structures formed by adsorption of organic molecules in Table VII. Similarly, coadsorbed overlayer structures and physisorbed overlayer structures are listed in Tables VIII and IX, respectively. The surface structures of high-Miller-index or stepped surfaces are listed in Table X. The trends and highlights in each sub-class are discussed in Section 4.

In recent years surface crystallography by LEED has successfully determined the precise location of the atoms within the surface unit cell (3 dimensional LEED), and the bond lengths and orientations of ordered adsorbed molecules have been also determined by this method.[4] A disordered monolayer structure has also been solved by LEED crystallography recently.[5] The surface structures that have been solved by LEED surface crystallography are marked with an asterisk "*" in the surface structure tables. The surface structures that were solved by surface science techniques other than LEED are marked with an exclamation sign "!" in the tables. These techniques include surface extended x-ray absorption fine structure (SEXAFS), medium energy ion scattering (MEIS) and high energy ion scattering (HEIS), etc.

2. The LEED Experiment

A schematical LEED experiment is shown in Fig. 1. A monoenergetic beam of electrons (10 eV to 300 eV) is directed at the surface of a single crystal which backscatters a portion of the incoming electrons. A set of hemispherical grids is used to remove the inelastically backscattered electrons while the elastically backscattered electrons are post-accelerated onto a phosphorous screen for viewing of the diffraction pattern. The crystal and the detection system are enclosed in a ultrahigh vacuum (UHV) chamber in order to attain and maintain a clean surface. The diffraction pattern on the phosphorous screen can be viewed and photographed from outside the UHV chamber. A polaroid camera is commonly used for photographing the diffraction pattern and the published LEED patterns are from such photographs.

LEED is commonly combined with other techniques such as Auger electron spectroscopy (AES), ultraviolet photoelectron spectroscopy (UPS), X-ray photoelectron spectroscopy (XPS), high resolution electron

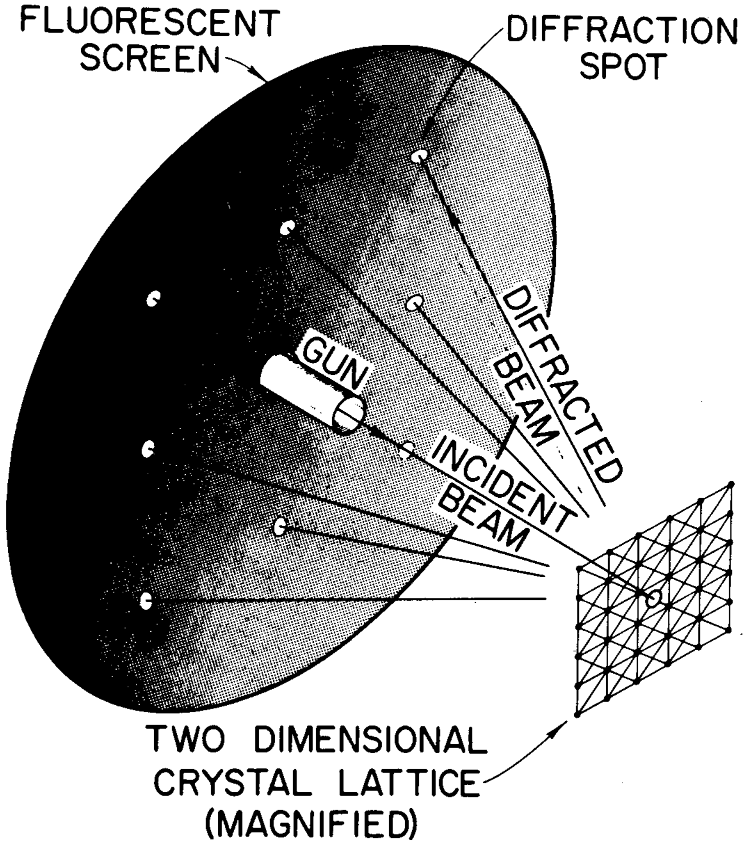

Fig. 1. Schematic of a low energy electron diffraction apparatus employing the post-acceleration technique. XBB 708-3583

energy loss spectroscopy (HREELS), and thermal desorption spectroscopy (TDS). This allows correlation of the surface structural information with other useful information on surfaces such as chemical composition, electronic properties, vibrational properties, and adsorption energetics.

A well ordered crystal surface will yield a diffraction pattern consisting of bright, well defined spots with very low background intensity. The sharpness and overall intensity of the spots depend on the degree of order of the surface. Although the surface may be somewhat irregular on the scale of a micron or more, the presence of sharp diffraction features indicates that the surface is ordered on an atomic scale, i.e., most of the surface atoms are located in a two-dimensional lattice structure.

The electron beam source commonly used yields an instrumental response width of about 100Å. This means that sharp diffraction features are obtained only if the regions of well-ordered atoms ("domains") have an area of $(100Å)^2$ or larger. Diffractions from smaller domains give rise to beam broadening.[6] Any random defects in the periodic array of atoms (including point defects and steps) gives rise to "diffuse intensity" in all directions.

Other types of LEED apparatus have also been developed, such as rear-view LEED[7] and low current electron-counting LEED[8] (or also called digital LEED). In the former case, phosphor is coated onto a transparent electrode substrate so that one can observe the diffraction pattern from the rear side of the LEED screen. This method is useful especially with bulky sample manipulators which otherwise would block a large part of the diffraction image. By using rear-view LEED, one can readily employ, for example, precision manipulators with azimuthal rotation or tilt capabilities, with heating and cooling capabilities, or with high pressure cell around the crystals.

Digital LEED shares these advantages with rear-view LEED. Digital LEED eliminates the phosphor screen, and instead directly measures the current due to the back scattered electrons from the sample using a position-sensitive detector. Because of the low beam current ($\sim 10^{-12}$ Amps) required for this technique, one can examine electron beam sensitive materials. Also, the high instrumental signal to noise ratio allows one to analyze diffuse LEED patterns due to the disordered surface structures.

3. Interpretation of the LEED Pattern and Notation for Surface Structures

A. General Case

LEED spot patterns represent the reciprocal lattice of the surface. The diffraction pattern must be inverted to real space in order to obtain the real-space periodicity. In this section we describe how this conversion is performed. First, the relationship between the reciprocal and real-space lattices of the substrate will be given. Then the determination of the surface periodicity from the LEED patterns will be discussed.

The pattern of spots has two-dimensional translational periodicity which is given by the vector $\vec{T}^*$, which has the form

$$\vec{T}^* = m^*\vec{a}^* + n^*\vec{b}^* \tag{3.1}$$

where m^* and n^* are integers and $\vec{a}^*$ and $\vec{b}^*$ are the basis vectors of the reciprocal unit cell. The reciprocal lattice, T^*, is related to the real-space lattice, $\vec{T}$,

$$\vec{T} = m\vec{a} + n\vec{b} \tag{3.2}$$

where m and n are integers and $\vec{a}$ and $\vec{b}$ are the basis vectors of the primitive surface lattice. The reciprocal unit cell vectors $\vec{a}^*$ and $\vec{b}^*$ are related to the real-space unit-cell vectors $\vec{a}$ and $\vec{b}$ by the following equations:

$$\vec{a}^* = \frac{\vec{b} \times \vec{z}}{\vec{a} \cdot (\vec{b} \times \vec{z})} \tag{3.3a}$$

$$\vec{b}^* = \frac{\vec{z} \times \vec{a}}{\vec{a} \cdot (\vec{b} \times \vec{z})} \tag{3.3b}$$

where $\vec{z}$ is normal to the surface. The relationship between the reciprocal and real-space vectors for a two-dimensional hexagonal lattice is shown in Fig. 2.

Reconstruction of the clean surface or adsorption of a gas on a surface usually results in a change in the diffraction pattern corresponding to the appearance of a new surface periodicity; the new lattice is called a superlattice. This is illustrated in Fig. 3, which shows a diffraction pattern of a clean Pt(111) surface and the diffraction pattern formed after the adsorption of an ordered layer of acetylene. Figure 4 shows the unit cells responsible for the diffraction patterns in Fig. 3 superimposed on a model of the Pt(111) surface. No information concerning the location of the adsorbate species within this unit cell (the location relative to the substrate atom positions) is indicated. This information can be obtained only from analysis of the diffraction spot intensities.

To make the transition from the diffraction pattern in Fig. 3 to the surface structure in Fig. 4, we need to reference the reciprocal superlattice to the reciprocal substrate lattice defined by the vectors $\vec{a}^*$ and $\vec{b}^*$. This

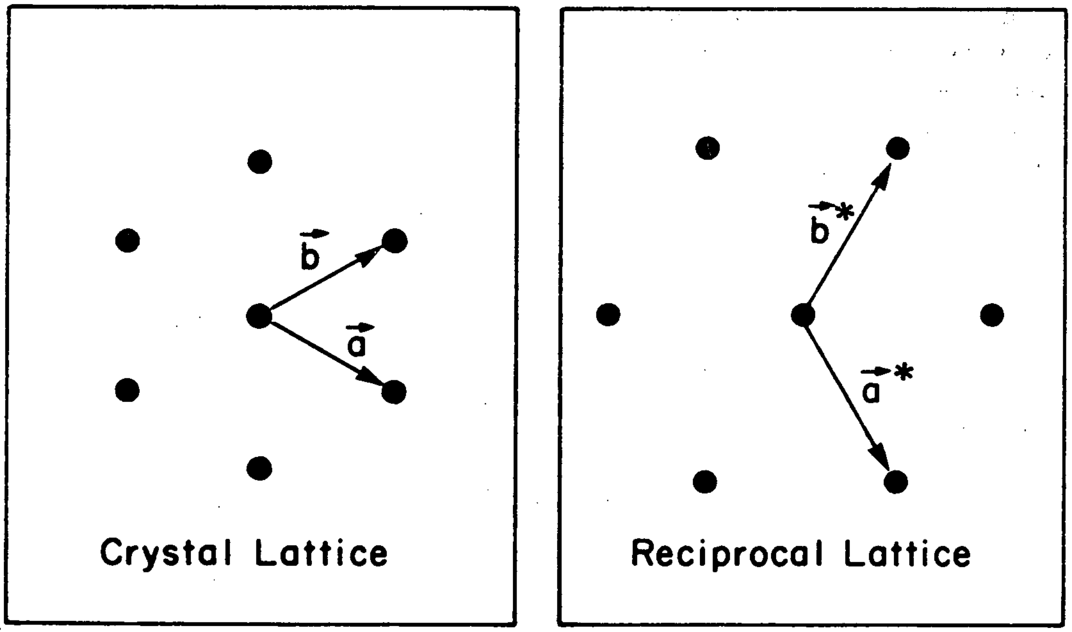

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Fig. 2. Real-space basis vectors $\vec{a}$ and $\vec{b}$ and reciprocal-space basis vectors $\vec{a}^*$ and $\vec{b}^*$ of a two-dimensional hexagonal lattice.

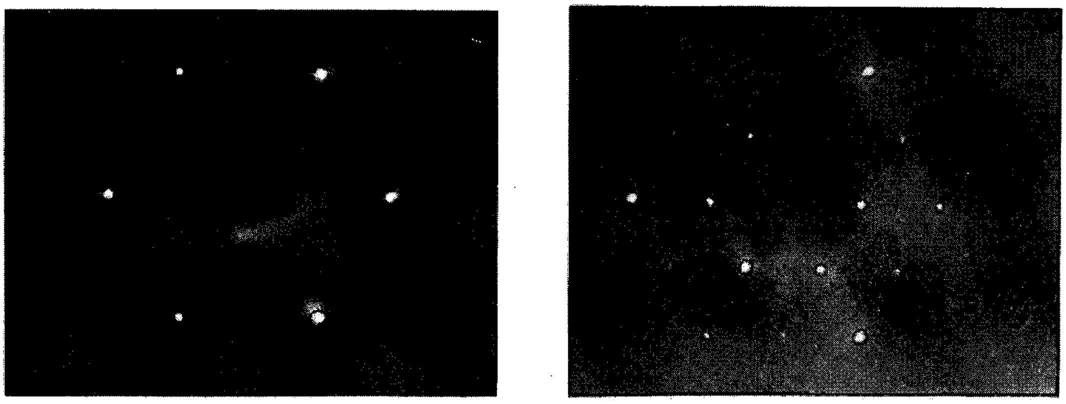

Fig. 3. LEED patterns of a clean Pt(111) (left) surface and the same surface with an ordered overlayer of acetylene (right). For both diffraction patterns, the incident beam energy is 68 eV. A spot of the center of the pattern and several other spots on the right in the patterns are invisible due to obstruction by the sample manipulator. XBB 750-8226

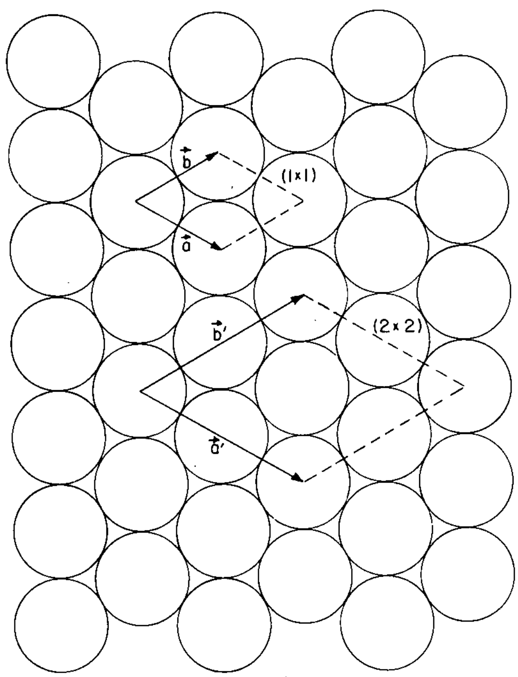

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Fig. 4. Real-space unit cells of Pt(111)-(1×1) and Pt(111)-(2×2)-C_2H_2 surface structures.

is carried out by a visual inspection of the diffraction pattern, in which the differences in spot intensities are neglected and only the positions of the diffraction beams are considered.

For the general case, the relationship of reciprocal substrate lattice to the reciprocal superlattice is given by the equations

$$\vec{a}^* = m_{11}^* \vec{a}^{*\prime} + m_{12}^* \vec{b}^{*\prime} \tag{3.4a}$$

$$\vec{b}^* = m_{12}^* \vec{a}^{*\prime} + m_{22}^* \vec{b}^{*\prime} \tag{3.4b}$$

where $\vec{a}^{*\prime}$ and $\vec{b}^{*\prime}$ are the basis vectors of the reciprocal superlattice and the coefficients m_{11}^*, m_{12}^*, m_{21}^*, and m_{22}^* define the matrix

$$M^* = \begin{pmatrix} m_{11}^* & m_{12}^* \\ m_{21}^* & m_{22}^* \end{pmatrix} \tag{3.5}$$

In real space the superlattice is related to the substrate lattice by the equations

$$\vec{a}' = m_{11} \vec{a} + m_{12} \vec{b} \tag{3.6a}$$

$$\vec{b}' = m_{21} \vec{a} + m_{22} \vec{b} \tag{3.6b}$$

where $\vec{a}'$ and $\vec{b}'$ are the basis vectors of the primitive superlattice and the coefficients m_{11}, m_{12}, m_{21}, and m_{22} define the matrix

$$M = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \tag{3.7}$$

The coefficients of the two matrices M and M* are related by the following equations:

$$m_{11} = m_{11}^* \quad , \tag{3.8a}$$

$$m_{12} = m_{21}^* \quad , \tag{3.8b}$$

$$m_{21} = m_{12}^* \quad , \tag{3.8c}$$

$$m_{22} = m_{22}^* \quad , \tag{3.8d}$$

so that if either M or M* is known, the other may be very easily obtained. In LEED experiments, M* is determined by visual inspection of the diffraction pattern and then transformed to give M, which defines the surface structure in real space.

For the case of ordered adsorption on Pt(111), visual inspection of the LEED patterns in Fig. 3 gives

$$M^* = \begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$$

The matrix M thus becomes

$$\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$$

so that $\vec{a}' = 2\vec{a}$ and $\vec{b}' = 2\vec{b}$, as depicted in Fig. 4.

A superlattice is termed commensurate when all matrix elements M_{ij} (i,j = 1,2) are integers. If at least one matrix element M_{ij} is an irrational number, then the superstructure is termed incommensurate. Superlattices can be incommensurate in one surface dimension or in both surface dimensions.

Alternatively to the matrix method of denoting surface structures, another system, originally proposed by Wood, is more commonly used. Whereas the matrix notation can be applied to any system, Wood's notation can only be used when the angle between the superlattcie vectors $\vec{a}'$ and $\vec{b}'$ is equal to the angle between the substrate vectors $\vec{a}$ and $\vec{b}$. If this condition is met, the surface structure is labeled using the general form

$$p(u \times v)R\Phi^\circ \quad \text{or} \quad c(u \times v)R\Phi^\circ \quad , \tag{3.9}$$

depending on whether the unit cell is primitive or centered (the prefix p is often dropped). In Wood's notation the adsorbate unit cell is related to the substrate unit mesh by the scale factors u and v, where

$$|\vec{a}'| = u|\vec{a}| \quad , \tag{3.10a}$$

$$|\vec{b}'| = v|\vec{b}| \quad . \tag{3.10b}$$

The label $R\Phi^\circ$ indicates a rotation of the superlattice by Φ° from the substrate lattice. For $\Phi = 0$, the $R\Phi^\circ$ label is omitted, so the surface structure in Fig. 4 is labeled as p(2 × 2) or simply (2 × 2). The label for the total system refers to the type of substrate, the superlattice periodicity, and the surface species. The platinum-acetylene adsorbate system shown in Fig. 4 would be labeled Pt(111)$-\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$-$C_2H_2$ in matrix notation and as Pt(111)$-$p(2 × 2)$-C_2H_2$ in Wood's notation. Wood's notation is more commonly used, and the matrix notation is usually applied only to systems to which Wood's notation does not apply, namely for which the angle between the superlattice vectors differs from the angle between substrate vectors.

An example of an adsorbate that produces a centered unit cell is shown in Figs. 5 and 6. In Fig. 5 diffraction patterns are shown from a clean Rh(100) surface and from a Rh(100) surface after exposure to one half monolayer of oxygen. By visual inspection it can be seen that

$$M^* = \begin{pmatrix} 1 & -1 \\ 1 & 1 \end{pmatrix}$$

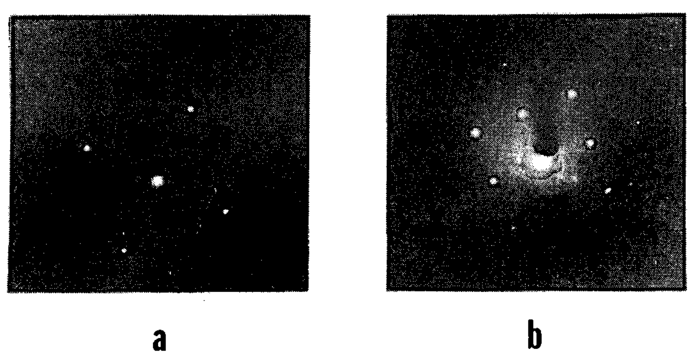

Fig. 5. LEED patterns of (a) clean Rh(100) at 74 eV, and (b) oxygen-covered Rh(100) at 85 eV. XBB 780-13148

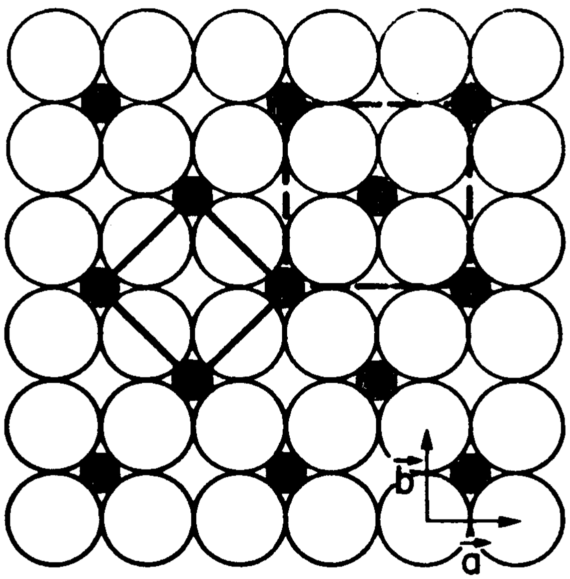

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Fig. 6. Real-space unit cells for the two notations $(\sqrt{2}\times\sqrt{2})R45°$ (solid lines) and $c(2\times2)$ (dashed lines) for an oxygen structure on the Rh(100) surface.

so Eqs. (3.8a–d) yield

$$M = \begin{pmatrix} 1 & 1 \\ -1 & 1 \end{pmatrix}$$

M defines the primitive unit cell of the adsorbate, which is drawn with solid lines in Fig. 6. This unit cell is labeled $(\sqrt{2}\times\sqrt{2})R45°$ in Wood's notation. Since the centered unit cell drawn in with dotted lines in Fig. 6 also describes the adsorbate unit cell, another way of labeling this structure would be $c(2 \times 2)$. The total system is labeled as Rh(100)$-\begin{pmatrix} 1 & 1 \\ -1 & 1 \end{pmatrix}$$-$O, Rh(100)$-(\sqrt{2}\times\sqrt{2})R45°$-O, or Rh(100)$-c(2 \times 2)-$O.

Unreconstructed surfaces of some common face-centered cubic (fcc), body-centered cubic (bcc), and hexagonal close-packed (hcp) crystal structures are shown in Fig. 7. The unreconstructed surface has a surface unit cell that is predicted by the projection of the bulk X-ray unit cell onto that surface. That unit cell is denoted as $p(1 \times 1)$ or (1×1) by Wood's notation. The same surface unit lattice is denoted by $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ in the more general matrix notation. In Table 1 several superlattices that are commonly detected on low-Miller-index surfaces are listed both by their matrix and by their Wood notations.

B. High−Miller−Index (Stepped) Surfaces

The atomic structures of high-Miller-index surfaces are composed of terraces, separated by steps, which may have kinks in them. For example, the (775) surface of an fcc crystal consists of (111) terraces, six atoms wide, separated by steps of $(11\bar{1})$ orientation and single-atom height.

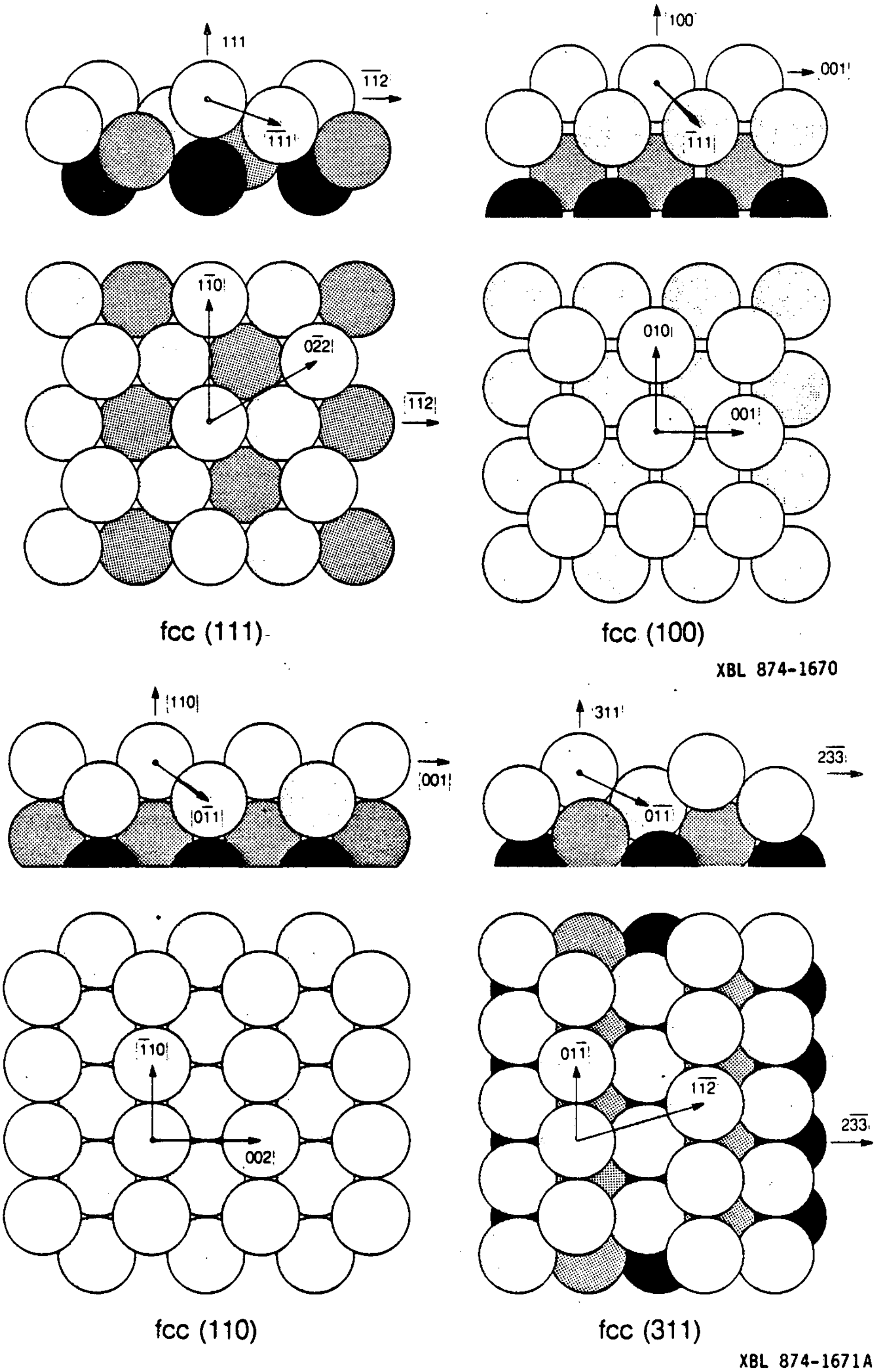
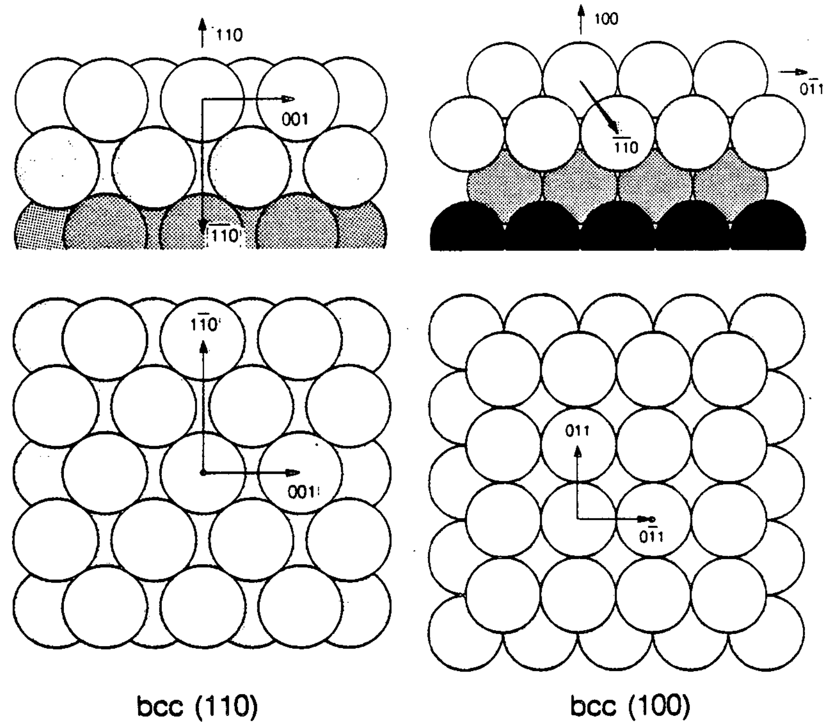


Fig. 7. Atomic arrangement in various unreconstructed, unrelaxed clean metal surfaces. In each panel, the top and bottom sketches give top and side views, respectively.



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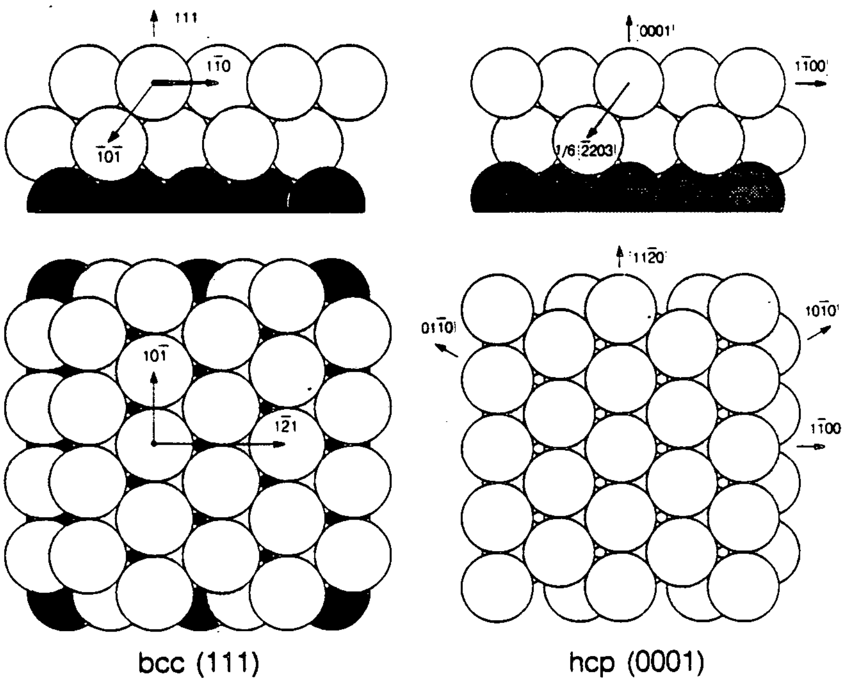

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Fig. 7. Continued.

Table 1. Wood and matrix notations for a variety of superlattices on low-Miller-index crystal surfaces.

Substrate	Superlattice unit cell: Wood notation	Superlattice unit cell: Matrix notation
fcc(100), bcc(100)	p(1×1)	$\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$
	c(2×2) = $(\sqrt{2} \times \sqrt{2})$R45°	$\begin{pmatrix} 1 & -1 \\ 1 & 1 \end{pmatrix}$
	p(2×1)	$\begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix}$
	p(1×2)	$\begin{pmatrix} 1 & 0 \\ 0 & 2 \end{pmatrix}$
	p(2×2)	$\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$
	$(2\sqrt{2} \times \sqrt{2})$R45°	$\begin{pmatrix} 2 & 2 \\ -1 & 1 \end{pmatrix}$
fcc(111) (60° between basis vectors)	p(2×1)	$\begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix}$
	p(2×2)	$\begin{pmatrix} 2 & 0 \\ 0 & 2 \end{pmatrix}$
	$(\sqrt{3} \times \sqrt{3})$R30°	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$
fcc(110)	p(2×1)	$\begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix}$
	p(3×1)	$\begin{pmatrix} 3 & 0 \\ 0 & 1 \end{pmatrix}$
	c(2×2)	$\begin{pmatrix} 1 & -1 \\ 1 & 1 \end{pmatrix}$
bcc(110)	p(2×1)	$\begin{pmatrix} 2 & 0 \\ 0 & 1 \end{pmatrix}$

The step notation devised by Lang and Somorjai[9] compacts this type of information into the general form

$$w(h_t k_t l_t) \times (h_s k_s l_s) \qquad (3.11)$$

where $(h_t k_t l_t)$ and $(h_s k_s l_s)$ are the Miller indices of the terrace plane and the step plane, respectively, while w is the number of atoms that are counted in the width of the terrace, including the step-edge atom and the in-step atom. Thus, the fcc(775) surface is denoted by $7(111) \times (11\bar{1})$, or also by $7(111) \times (111)$ for simplicity. A stepped surface which has steps that are themselves high-Miller-index faces is termed a kinked surface. For example, the fcc(10,8,7) = $7(111) \times (310)$ surface is a kinked surface. The step notation is, of course, equally applicable to surfaces of bcc, hcp, and other crystals, in addition to surfaces of fcc crystals. However, the overwhelming majority of experimental research on high-Miller-index surfaces has utilized fcc crystals.

There is another notation called "microfacet notation" developed by Van Hove and Somorjai.[10] This notation is based on the idea that any Miller-index-vector (hkl) which specifies a certain crystal face can be decomposed in terms of three linearly independent vectors such as (111), (110), and (100). For example the fcc(10,8,7) kinked surface has the microfacet notation, fcc[7_{14}(111)+1_1(110)+2_2(100)]. By using this notation, we can easily recognize that the (10,8,7) unit cell contains fourteen unit cells of the (111) microfacet, one unit cell of the (110) microfacet, and two unit cells of the (100) microfacet.

The surface structures observed on stepped surfaces are listed in Table X. Here the crystal faces are denoted either by their Miller indices or by their stepped surface notation, depending on which system was used by the original authors. Table 2 describes the correlation between these two notations for fcc crystals. Using this table, one may convert back and forth between the two notations.

Table 2. Correspondence between the Miller-Index Notation and Stepped Surface Notation

Miller Index	Stepped Surface Designation	Angle Between the Macroscopic Surface and Terrace (degrees)
(544)	(S)-[9(111)×(100)]	6.2
(755)	(S)-[6(111)×(100)]	9.5
(533)	(S)-[4(111)×(100)]	14.4
(211)	(S)-[3(111)×(100)]	19.5
(311)	(S)-[2(111)×(100)]	29.5
	(S)-[2(100)×(111)]	25.2
(511)	(S)-[3(100)×(111)]	15.8
(711)	(S)-[4(100)×(111)]	11.4
(665)	(S)-[12(111)×(111)]	4.8
(997)	(S)-[9(111)×(111)]	6.5
(332)	(S)-[6(111)×(111)]	10.0
(221)	(S)-[4(111)×(111)]	15.8
(331)	(S)-[3(111)×(111)]	22.0
	(S)-[2(110)×(111)]	13.3
(771)	(S)-[4(110)×(111)]	5.8
(610)	(S)-[6(100)×(110)]	9.5
(410)	(S)-[4(100)×(110)]	14.0
(310)	(S)-[3(100)×(110)]	18.4
(210)	(S)-[2(100)×(110)]	26.6
	(S)-[2(110)×(100)]	18.4
(430)	(S)-[4(110)×(100)]	8.1
(10,8,7)	(S)-[7(111)×(310)]	8.5

4. Review of Surface Structures Studied with LEED

Tables I–X list over 3,000 surface structures, most of which have been reported within the past several years. The low-Miller-index metal surfaces and atomic adsorbates were studied predominantly in earlier years. In recent years more emphasis has been put on the polyatomic solids (compounds, alloys) surfaces, high-Miller-index stepped surfaces and the molecular overlayers with increasing complexity.

We shall in this section discuss some of the important trends that can be extracted from the surface structure tables.

A. Ordering Principles

As our Tables I–X show, a large number of ordered surface structures can be produced experimentally. Ordering can manifest itself both as commensurate and as incommensurate structures. There are also many disordered surfaces, which often are not reported in the literature. The disordered structures are usually difficult to describe accurately and are therefore difficult to reproduce exactly in other laboratories. Nevertheless, for selected surfaces, order-order and order-disorder phase transitions have been explored in considerable detail both experimentally and theoretically.

In our tables, a number of disordered surface structures are listed. However, it should be stressed that many structures reported as having a (1×1) LEED pattern may well include small or large amounts of disorder, whether in the overlayer structure or even in the substrate structure.

(i) Adsorbate–adsorbate and adsorbate–substrate interactions. The driving force for surface ordering originates, analogous to three-dimensional crystal formation, in the interactions between atoms, ions, or molecules in the surface region. The physical origin of the forces is of various types, and the spatial dependence of these interaction forces is complex.

For adsorbates, an important distinction must be made between adsorbate-substrate and adsorbate-adsorbate interactions. The dominant adsorbate-substrate interaction is due to strong covalent or ionic chemical forces between the adsorbates and the substrate in the case of chemisorption, or to weak Van der Waals forces in the case of physisorption. Adsorbate-adsorbate interactions could be covalent bonding interactions, orbital-overlapping interactions, electrostatic interactions (ex. dipole-dipole interactions), Van der Waals interactions, etc. These are many-body interactions that could be attractive or repulsive depending on the system.

In chemisorption it is usually the case that the adsorbate-adsorbate forces are weak compared to the adsorbate-substrate binding forces (except at very close repulsive range, since atoms will not overlap). Chemisorbed species with strong unbalanced adsorbate-adsorbate forces will not be stable, and will easily undergo rearrangement or surface chemical reaction to transform into a more stable state. The adsorbate-substrate interaction includes a corrugation parallel to the surface, favoring certain adsorption sites over others and implying barriers to diffusion. This imposes the constraint that only lattice sites be occupied. With weak adsorbate-adsorbate forces the locations of the adsorbed atoms or molecules are determined by the optimum adsorbate-substrate bonding. But the adsorbate-adsorbate interactions still manage to dominate the long-range ordering of the overlayer.

A compromise is found in the formation of an adsorbate lattice that is simply related to the substrate lattice. In the ordered case this yields commensurate superlattices. The most common of these are simple superlattices with one or two adsorbates per superlattice unit cell. They occur for adsorbate coverages of 1/4, 1/3, 1/2, for example (we define the surface coverage to be unity when each (1×1) substrate cell is occupied by one adsorbate).

A special case of commensurate superlattice is the formation of periodic out-of-phase domains. They occur especially when the adsorbate coverage is not well matched to form a simple ordered lattice. Then equal domains of simple structure are mismatched to each other through dislocations (domain walls) that allow higher or lower coverages. It is not entirely straightforward to experimentally distinguish the periodic domain structures from the incommensurate structures. Therefore, many structures are found labeled as incommensurate in the literature, even though they are probably of the periodic-domain type.

An incommensurate relationship exists when there is no common periodicity between an overlayer and the substrate. This structure is dominated by adsorbate-adsorbate interaction rather than by adsorbate-substrate interactions. An example of incommensurate lattice formation occurs frequently when compounds are produced by exposure of an elemental substrate to a gas. Examples are metal oxides, nitrides, carbides and silicides. As soon as about one or two monolayers of the compound form on the surface, they frequently adopt their own lattice constant independently of the substrate lattice constant. This is because the attractive forces within the compound can be much stronger than those between the compound and the substrate.

(ii) Effects of adsorbate coverage. The surface coverage of an adsorbate is an important parameter in the ordering process. This is because the adsorbate-adsorbate and the adsorbate-substrate forces are strongly influenced by the surface coverage of the adsorbates. (An extreme case is alkali-metal adsorption on transition metal surfaces, where the ionicity of the adsorbate-substrate bond changes as the surface coverage increases.) At very low coverages, adsorbates may bunch together in two-dimensional islands: this occurs when there is short-range attractive adsorbate-adsorbate interactions, coupled with easy diffusion along the surface. Within each island the interactions induce an ordered arrangement of adsorbates. Other adsorbates repel each other at close adsorbate-adsorbate separations, and do not interact at the large separations: these are disordered at low coverages. But when their coverage is increased so that the mean interadsorbate distance decreases to about 5–10Å, the repulsive interactions induce and strongly influence ordering, favoring certain adsorbate configurations over others. As a result, the structure can also develop a unit cell that repeats periodically across the surface. This is most clearly evident in the low-energy electron diffraction patterns, which depend directly on the size and orientation of this unit cell.

Most adsorbates (other than some metals) will not compress into a one-monolayer overlayer on the closest-packed metal substrates. There appears to be a close-range repulsive force that keeps them apart by approximately a Van der Waals distance (this does not necessarily imply a Van der Waals interaction, since the strongest contribution to the adsorbate-adsorbate interaction is in this case mediated by the substrate). One may attempt to compress the overlayer further by increasing the coverage, which is done by exposing the surface to the corresponding gas at high pressures. The result is either no further adsorption or diffusion of the adsorbates into the substrate, forming compounds, or, if the temperature is low enough, formation of multilayers.

(iii) Physical adsorption. When adsorbates are used which physisorb rather than chemisorb (at suitably low temperatures), one also finds that the Van der Waals distance determines the densest overlayer packing. Here it is the Van der Waals force acting directly between the adsorbates that dominates. In this case, the optimum adsorbate-substrate bonding geometry can be overridden by the lateral adsorbate-adsorbate interactions, yielding for example incommensurate structures where the overlayer and the substrate have independent lattices. Furthermore, with physisorption a larger coverage is also possible through multilayer formation.

(iv) Metallic adsorbates. With metallic adsorbates, on the other hand, closer-packed overlayers can be formed. This is because metallic adsorbate atoms attract each other relatively strongly to form covalent bonds and cluster together with covalent interatomic distances. Thus at submonolayer coverages close-packed islands form. When the atomic sizes of the overlayer and substrate metals are nearly the same, one observes single-monolayer (1×1) structures, in which adsorbate atoms occupy every unit cell of the substrate. With less equal atomic radii, other structures are formed, dominated by the covalent closest packing distance of the adsorbate. These structures may be of the incommensurate type or, more likely, of the periodic-domain type. Beyond one close-packed overlayer, metal adsorbates frequently form multilayers or also three-dimensional crystallites. Alloy formation by interdiffusion is also observed in many cases, even in the submonolayer regime.

B. Surface Restructuring

There are many observations of deviations of a clean surface structure from the structure predicted by a simple truncation of the bulk lattice. Many LEED patterns of clean surfaces listed in Tables I–IV and X deviate from the expected (1×1) pattern. These are relatively drastic cases where atoms may be displaced substantially from their bulk lattice sites and bonded to different atoms than the bulk structure would imply. Such cases are called reconstructions. Another cause of reconstruction is, as seen at compound surfaces, a change in elemental composition at a surface compared to the bulk composition. A different crystalline lattice may become favored as the surface composition changes due to segregation to or from the surface. Non-stoichiometric compounds often exhibit this behavior. A more subtle restructuring has also been discovered during full structural determinations. Layer spacing relaxations have been found between the first few surface layers of the less close-packed clean metal surfaces, e.g., fcc (110) and bcc(100). These relaxations correspond to deviations of the surface bond lengths from the bulk values, but do not affect the LEED pattern.

Among the clean metal surfaces, about a dozen are known to reconstruct. Over 40 clean semiconductor reconstructions are reported. Numerous reconstructions have also been found in the area of oxides and other compounds. (See the LEED patterns of clean surfaces in Tables I–IV, and X.)

Some of these reconstructions and layer spacing relaxations can be explained by the tendency for bond lengths to decrease as the bonding coordination decreases. This trend fits long-established principles, as proposed by Pauling,[11] if one relates coordination number to bond order. A good illustration is presented by the reconstructions of the clean Ir, Pt and Au(100) surfaces. In these three cases, the interatomic distance in the topmost layer shrinks by a few percent parallel to the surface. It then becomes more favorable for this layer to collapse into a nearly hexagonally close-packed layer rather than maintain the square lattice of the underlying layers. Many adsorbates on these surfaces can remove this reconstruction by cancelling the driving force towards smaller bond lengths.

In these studies surface cleanliness is monitored by various techniques including AES, XPS, HREELS, etc., and the sample is cleaned until the concentration of impurities is below the detection threshold of these techniques (a few hundredths of a monolayer). However, it is always risky to conclude that a reconstruction is a property of the clean surface, since it is very difficult to rule out the presence of at least some contaminants. Nevertheless, it is now believed that most of the nominally clean reconstructions are intrinsic properties of the clean surfaces, and are only marginally affected by small levels of impurities. This is the case of the Ir, Pt and Au(100) surfaces mentioned above.

At the same time it is also known that a fair number of reconstructions are adsorbate-induced. Even without being ordered, an adsorbate can induce a reconstruction, as happens with H on W(100). The clean W(100) crystal surace is itself already reconstructed, but hydrogen changes it further to another structure that varies smoothly with the hydrogen coverage. Often, the adsorbate fits periodically within the unit cell of the reconstructed substrate. This occurs, for example, with carbon on Ni(100) and sulfur on Fe(110), where the metal exhibits relatively minor, but interesting adsorbate-induced distortions.

Adsorbates can also restructure stepped surfaces. For example, oxygen deposited on stepped Pt surfaces has been observed to produce double-height steps. Facetting has also been observed under such circumstances.

By contrast, it is also possible, with contaminants or otherwise, to generate a metastable unreconstructed phase from a reconstructed clean surface. With suitable contaminants, such phases have been achieved with all reconstructed surfaces. In some cases, e.g., Ir(100), clean metastable structures can be obtained by appropriate heat treatments. Si(111)-(1×1) metastable unreconstructed structure can also be achieved by laser-annealing and rapid cooling processes which freeze the unreconstructed structure which is stable at high temperature.

In the case of alloys, surface segregation can lead to new ordered arrangements, through a change in the surface composition. In some cases, for instance CuAl(111) with a bulk composition of 16% of Al, the surface alloy orders while the bulk alloy has no long-range order. Such cases are reported in our tables as having a superlattice (e.g., for the above-mentioned CuAl case), by reference to the (1×1) lattice of the pure majority element. One may call these alloy reordering reconstructions. They involve essentially normal lattice sites, but a different ordering at the surface compared to the bulk.

Semiconductors almost universally reconstruct when clean. This is due to the difficulty of their surface atoms to compensate for the loss of nearest neighbors, since bonding is relatively directional in semiconductors. The "dangling bonds" left by the absence of bonding partners cannot easily be used for bonding to existing surface atoms, except through more drastic rearrangements of these atoms. Therefore, most semiconductor surfaces reconstruct. Major rebonding between surface atoms occurs in this process. The associated perturbation propagates several layers into the surface until the bulk lattice is recovered. The silicon surfaces in particular have been extensively studied in their various reconstructed forms. The famous Si(111)-(7×7) structure has not yet been solved, but so much information has been gathered, including real-space topographies of this surface obtained with STM, that a good qualitative picture of its structure is becoming apparent.[12] Again with semiconductor surfaces, adsorbates can negate the need for reconstruction and induce a return to the bulk structure. This can happen by bonding of the adatoms to the "dangling bonds." Hydrogen does this particularly well and to some extent chemically passivates the resulting surface. More frequently, however, adsorbates become part of a new compound structure, by penetrating within the few topmost substrate layers.

The stoichiometry is also important in considering the reconstruction of compound semiconductors. For example a $(\sqrt{5}\times\sqrt{5})R26.6°$ structure of $BaTiO_3(100)$ surface observed after high temperature annealing is considered to be due to the ordering of lattice vacancies at the surface. Another example is the GaAs(100) surface which presents various reconstructed structures as the Ga to As ratio changes. Relatively little structural knowledge has been accumulated so far on this subject, despite the great technological importance of semiconductor surfaces and the semiconductor-metal interface.

C. Simple Structures of Atomic Adsorbates at Metal Surfaces

By simple structures we mean clean unreconstructed metal surfaces with low Miller indices and atomic adsorbates thereon. These were the mainstay of the early LEED studies and constituted the bulk of earlier tabulations. In recent years this class of structures has continued to grow, mostly through new combinations of substrates and adsorbates.

The clean unreconstructed metal surfaces, by definition, have the structure expected from a simple truncation of the bulk lattice. For close-packed surfaces with low Miller indices, relaxations from the bulk atomic positions have been found to be less than about 0.02Å by various crystallographic methods, especially, LEED and MEIS or HEIS. For the more open surfaces, such as fcc(110) and bcc(100), somewhat larger relaxations have been observed, as mentioned in the previous section.

The simple atomic adsorption structures on metal surfaces are characterized by the occupancy of high-coordination sites. (Physisorption behaves differently and will be discussed in Section 4.H). Thus Na, S, and Cl overwhelmingly adsorb over "hollows" of the metal surface, bonding to as many metal atoms as possible. The situation is slightly more complicated with the smaller adsorbates, H, C, N, and O. Although high coordination is still preferred, the small size of these atoms often allows penetration within or even below the first metal layer. The penetration can be interstitial or substitutional. In either case the metal surface can reconstruct as a result.

D. Metallic Monolayers on Metal Crystal Surfaces

Table V lists surface structures of metal monolayers adsorbed on metal surfaces. Data on more than 400 systems have been reported so far.

At low coverages, most of the metallic adsorbates form commensurate ordered overlayers: the overlayer unit cells are closely related to the substrate unit cells. Furthermore, in many cases a (1×1) LEED pattern is observed. This suggests that adsorbed metal atoms attract each other to form 2-dimensional islands. The size of such islands can change depending on the substrate temperature, which can be detected by measuring the LEED spot size. A disordered LEED pattern is observed when the adsorbed metals repel each other. This is observed for example in the case of alkali metal adsorption on a transition metal, since the charged adatoms undergo repulsive interactions.

At higher coverages, the relative atomic sizes of the different metals becomes an important factor. When the atomic sizes of the substrate and adsorbate metals are similar, (1×1) structures are favored, whereas coincidence structures often form when the atomic sizes are much different. As the overlayer coverage increases towards saturation of a monolayer, the adsorbate-adsorbate interaction increases. Then an incommensurate hexagonal overlayer with interatomic distances close to the bulk value of the adsorbate appears to form. Another, perhaps more satisfactory interpretation of the LEED patterns yields an overlayer structure with out-of-phase domains, reflecting the remaining strength of the substrate-adatom interaction. In the case of strong adatom-adatom attraction and weak substrate-adatom attraction, one observes the independent superposition of the structures of the pure adsorbate and the pure substrate. Often such dense overlayers have a lattice that is slightly rotated with respect to the substrate lattice. This has also been experimentally observed and theoretically predicted for physisorbed films,[13] and is called "orientational epitaxy."

Under higher exposure some metals can undergo layer-by-layer growth, while several systems, such as Fe on W(110), form 3-dimensional crystallites. Most cases fall between these two extremes. Comparison of the surface tension of the adsorbate metal and of the substrate metal has failed to explain these phenomena, and up to now there is no simple rule to predict which metal film growth mechanism applies.

When a metal undergo as (1×1) epitaxial growth with a substrate lattice constant that differs from its own bulk lattice constant, the overlayer metal can be considerably strained. Therefore, the epitaxial growth must at some point be accompanied by a lattice constant change. Such a change is probably accompanied through dislocations occurring within a dozen layers from the interface.

Alloy formation is frequently observed with suitable combination of metals, usually at higher temperatures. However very little surface crystallographic data is available on such systems, and a general trend cannot be drawn at this time.

E. Alloy Surface Structures

Our Tables include about 90 surface structures of alloys, including both clean and adsorbate-covered surfaces. These are brought together in Table VI. Alloys have the special property that their surface composition can differ considerably from their bulk composition. Other compounds share this property, but the frequently easy interdiffusion in alloys stands out. Indeed, some recent studies have found substantial surface segregation. In some cases the surface composition can even oscillate from one atomic layer to the next near a surface. Furthermore, adsorbates may radically modify this surface composition. Much work is needed to clarify these issues.

The LEED pattern informs about the surface ordering. It is found that some alloys retain their bulk ordering at the surface. For instance, Ni_3Al, as well as other Cu_3Au-type alloys, have a (100) face which exhibits the periodicity expected from the alternating bulk stacking of 50–50 mixed NiAl layers and of pure Ni layers. (Some authors refer to these surface structures as $c(2\times2)$: we prefer the notation (1×1) since the bulk periodicity is not changed.)

Other alloys, exemplified by Cu-rich CuAl, are disordered in the bulk, but order at some faces. Thus the (111) face of αCu-16at%Al exhibits a $(\sqrt{3}\times\sqrt{3})R30°$ surface periodicity (relative to the (1×1) surface lattice of pure Cu(111)). The other low-Miller-index faces of this alloy do not order.

F. Organic Adsorbates

Around 390 LEED structures are reported in Table VII, dealing with the adsorption of organic molecules. By far the most frequently studied substrates are metals, with only a dozen cases of semiconductors or insulators. Platinum substrates have been most extensively used, due no doubt to their importance in both heterogeneous catalysis and electrochemistry. The most common adsorbates in this table are C_2H_2 (acetylene), C_2H_4 (ethylene), C_6H_6 (benzene), C_2H_6 (ethane), HCOOH (formic acid), and CH_3OH (methanol), reflecting the same technological applications.

Most organic adsorption studies have been carried out near room temperature, with frequent cursory explorations of the higher-temperature behavior. Especially with organics, temperature is a crucial variable, given the frequently diverse reaction mechanisms that can occur when molecules interact with surfaces. A number of studies have explored the lower temperatures, especially with the relatively reactive metal surfaces to the left of the Periodic Table, such as Fe, Mo, and W. At higher temperatures, decomposition of molecules is the rule. With hydrocarbons sequential decomposition has been studied in greatest detail with the help of HREELS vibrational analysis.

The LEED patterns generally reflect disorder at high temperatures. Exceptions occur especially with carbon layers resulting from the decomposition of organic adsorbates: these may form either carbidic chemisorbed layers that are ordered or graphitic layers that have characteristic diffraction patterns.

Ordered LEED patterns for organic adsorption are frequent at lower temperatures. They can often be interpreted in terms of close-packed layers of molecules, consistent with known Van der Waals sizes and shapes. These ordered structures usually are commensurate with the substrate lattice, indicating strong chemisorption in preferred sites. It appears that many hydrocarbons lie flat on the surface, using unsaturated π-orbitals to bond to the surface. By contrast, non-hydrocarbon molecules form patterns that indicate a variety of bonding orientations. Thus CO is found to strongly prefer an upright orientation. However, upon heating unsaturated-hydrocarbon adsorbates evolve hydrogen and new species may be formed which bond through the missing hydrogen positions. An example is ethylidyne, CCH_3, which can be formed from ethylene, C_2H_4, upon heating. Ethylidyne has the ethane geometry, but three hydrogens at one end are replaced by three substrate atoms.

G. Coadsorbed Surface Structures

Table VIII brings together surface structures formed upon coadsorption of two or more different species. Listed are ~150 structures. In general, coadsorbed surface structures may be classified in two categories: cooperative adsorption and competitive adsorption. In cooperative adsorption, the two kinds of adsorbate mix well together and interpenetrate. In competitive adsorption the adsorbates segregate to form separate non-mixed domains. For example, addition of CO to a preadsorbed (2×2) oxygen layer on Pd(111) eventually forms a mixed CO+O phase (cooperative adsorption). On the other hand, addition of O_2 to a preadsorbed CO layer (at low coverages: $\theta < 0.33$) on Pd(111) forms separate domains of O and of CO (competitive adsorption). Therefore, in this instance the order of adsorption affects the reactivity towards CO_2 formation.

Coadsorption structures have been extensively examined on Rh(111), Pt(111), and Pd(111) using various pairs of adsorbates from the set C_2H_2, C_2H_3 (ethylidyne), C_6H_6, Na, CO, and NO. Among these, the hydrocarbons and Na transfer electrons to Rh(111) when adsorbed: they are donors. CO and NO have the opposite electron-transfer character, and are therefore acceptors. It has been observed that long-range ordering of the mixed layer requires the coadsorption of an electron donor with an acceptor. Donor-donor and acceptor-acceptor combinations are either disordered or segregate into separate regions. The combination of donor and acceptor seems to stabilize the mixed cooperative phase. Then each donor adsorbate surrounds itself with acceptors, while each acceptor surrounds itself with donors. This is analogous to the three-dimensional ionic lattices which also exhibit great stability.

As an illustration, on Pd(111) and Pt(111), benzene molecules adsorb in a disordered manner at room temperature. However, addition of CO to these disordered overlayers produces ordered surface structures.

H. Physisorbed Surface Structures

At low enough temperatures most gas-phase species will physisorb on many surfaces. In many instances, the physisorbed state is short-lived (lifetime well below a second), because of a low barrier to a chemisorbed state. With inert gases and with saturated hydrocarbons, however, physisorption is commonplace and stable on many types of substrate. These substrates include metals as well as inert surfaces such as the graphite basal plane. Also, more reactive species such as O_2, CO and NO physisorb stably on the graphite basal plane. We shall focus our discussion on this type of relatively stable physisorption. Over 60 such structures are listed in Table IX. Little is known about the structure of the less stable short-lived physisorbed species, despite their obvious importance as precursors to chemisorbed species.

In physisorption the adsorbate-adsorbate interactions are usually comparable in strength to the adsorbate-substrate interactions, all of which are dominated by the Van der Waals forces. With stable physisorption, there is no chemistry to perturb the adsorbates over large ranges of temperature and coverage. One can therefore examine large parts of the phase diagrams of these adsorption systems.

Many phases have been observed in physisorption, and new classes of phases continue to be discovered. There are commensurate and incommensurate phases, disordered lattice-gas and fluid or liquid phases. There are out-of-phase domain structures, including striped-domain phases, pinwheel and herringbone structures, and modulated hexatic reentrant fluid phases, among others.[4] Relative to chemisorption and its more complex interactions, physisorption has the advantage that simpler theories can be set up to describe the phase diagrams. The two-dimensional nature of the problem has especially helped the general theory of phase transitions, because many models can only be solved in two dimensions.

From the point of view of physisorption phases, one should distinguish between the ordering of the positions and the orientations of the adsorbed species. With spherically symmetrical species like inert gases this is not an issue, but all molecules do offer the additional degrees of orientational freedom, which freeze in at different temperatures than does the positional ordering. This adds considerable richness to the phase diagrams.

The simpler among the observed LEED patterns for physisorbed species can often be easily interpreted in terms of structural models. The known Van der Waals sizes of the species leads to satisfactory structures which are more or less close-packed. This is especially straightforward with inert gases. With molecules, the best structural models usually involve flat-lying species, which are arranged in a closest-packed superlattice. The flat geometry provides the greatest attractive Van der Waals interaction with the substrate.

I. High—Miller—Index (Stepped) Surface Structures

Over 380 surface structures have been observed on the high-Miller-index surfaces, see Table X. About 250 of these were reported during the past six years, which clearly indicates a fast growing interest in this field. In this period, much work has focussed on the clean and chemisorbed structure of high-Miller-index semiconductor surfaces. In particular, very interesting reconstructions of the various high-Miller-index Si, Ge and GaAs surfaces have been observed.

Most of the stepped surfaces reported in Table V have close-packed terraces separated by steps of one atomic height. Many ordered overlayer structures on these one-atomic-height stepped surfaces have been reported. The observed LEED patterns indicate a strong dependence on the width of the terraces. With wide terraces, adsorbates often order as if no steps were present, i.e., as on the low-Miller-index surface. When the terraces become narrow, the adsorbates are strongly affected by the steps. For instance, carbon monoxide adsorbs with (2×2) and $(\sqrt{3}\times\sqrt{3})R30^\circ$ patterns on Rh(S)-[6(111)×(100)], which has (111) terraces six atoms wide separated by (100) oriented steps. These two patterns are also observed on Rh(111). But for the case of Rh(331) with (111) terraces three atoms wide, quite different structures for chemisorbed CO have been observed.

Another important observation is that reconstructions of the high-Miller-index surfaces are frequently induced by the adsorption of O_2, H_2, etc. Examples include: ReO_3 compound formation on the oxygen covered Re(S)-[6(0001)×$(16\bar{7}6)$] surface; new facet formation on the Ni(210) surface after the adsorption of O_2; facet formation due to the decomposition of hydrocarbons on various Pt and Rh high-Miller-index surfaces; and graphite formation or faceting on Pt(S)-[4(111)×(100)] after the total dehydrogenation of ethylene or benzene on this surface. These restructuring phenomena can often be ascribed to the formation of a stable new phase like oxide, carbide, and nitride. The study of the surfaces of oxide-, carbide- and nitride-solids will help understand the restructuring phenomena observed on the stepped surfaces.

A comment about the superlattice notation for stepped surfaces: an adsorbate superlattice designation like (2×2) is meant to imply a superlattice relative to the close-packed lattice within a terrace, rather than relative to the step-to-step repetition distance.

5. Future Directions

The solid surface presents a two-dimensional world where molecules may order and interact differently from that in three dimensions. Surface restructuring of many solids when clean either by relaxation or by reconstruction clearly indicates this. When investigating polyatomic solids, compounds or alloys, the surface composition will also be different than the bulk composition to provide on additional important variable that alters the surface structure; non-stoichiometry.

We should mentión several monoatomic solids including boron, manganese and uranium that escaped the attention of surface scientists. However, future studies clearly will focus on surfaces of increasing chemical complexity. These include high-Miller-index (stepped) surfaces, and the surface structures of diatomic and polyatomic solids, the oxides, sulfides, carbides, nitrides, silicates, carbonates, as well as alloys. Many more adsorption structures will also be explored on semiconductor surfaces. Organic molecules of increasing size will be investigated and it is very likely that the surfaces of organic solids will be the subjects of structural studies as they are most important in the biosciences and chemical technologies. Coadsorption will continue to expand as an area of interest for the study of chemical reactions including the effects of promoters and inhibitors. Underexplored adsorbates include inorganic molecules (with the exception of CO and NO). Also semiconducting materials are rarely deposited on metals, while metals are currently very much studied on semiconducting substrates.

One interesting observation recently has been the ordering of adsorbed monolayers at low temperatures as low as 30 K for CO and 60 K for C_2H_2 on close-packed metal surfaces.[14] This finding indicates the low activation energy for surface diffusion as compared to desorption of these molecules. It is likely that adsorbate surface structures will be studied increasingly at low temperatures as a consequence.

Rapid dynamical surface structure calculations have become possible due to recent developments of simplified computational techniques.[15] This way the precise locations of atoms and molecules in the surface unit cells can be determined. The surface structures listed in Tables I–X are excellent candidates for surface crystallography investigations. It is hoped that a large number of them will be scrutinized by LEED crystallography in the near future so that we can improve our understanding of the surface chemical bonds in atomic and molecular monolayers.

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TABLE I. Surface Structures on Substrates with One-fold Rotational Symmetry†

Substrate	Adsorbate	Surface Structure	Reference
(Al,Ga)As(110)	[clean]	(1×1)	1375
AlP(110)	[clean]	*(1×1)	1521,1863*
CdTe(110)	[clean]	*(1×1)	1367,1382*,1495 1504,1620
CoSi(100)	[clean]	(2×1)	1312
$CoSi_2$(100)	[clean]	(1×1)	1312
GaAs(110)	[clean]	*!(1×1)	896,949,1008,1090,1124,1182 1449,1480,1519 1524,1567,1572 1575,1576,1702* 1764*,1765!
		(2×2)	1567
	Ag	(1×1)	1575
		[001] Streaks	1575
		c(4×4) [Multilayer]	1344
	Al	(1×1)	1375,1432,1607
	Al (low coverage)	*(1×1)–Al	1871*
	Al (medium coverage)	*(1×1)–Al	1871*
	Al (high coverage)	*(1×1)–Al	1871*
		(1×4) [Multilayer]	1344
	As	(1×1)	579,1375
	Au	Disordered	1008
	Cu	Polycrystalline	1182
	Ga	Polycrystalline	1305
		(1×1) [Multilayer]	1432
	Ge	(1×1)–Ge	1089,1520,1572
		(3×1)–Ge	588
		(2×1)–Ge	588
		(3×1)+(1×4) with Streaks	1089
		(1×1)+Blurred (8×10)	1089
	H_2O	(1×1)	1006
	In	(1×1)	1432
	$Fe(CO)_5$	Facet{100}	1377
	O_2	Disordered	744
	Pd	Disordered	1008
	Sb	*(1×1)–Sb	1320,1367,1383 1424,1442*
	ZnSe	(1×1)	1444
		(1×2)	1444
GaP(110)	[clean]	*(1×1)	819,1445*,1495 1521,1619
	Al	AlP(110)	1426
		(1×1)	1521
GaSb(110)	[clean]	*!(1×1)	1378*,1420*,1766!
InAs(110)	[clean]	*(1×1)	1423*
InP(110)	[clean]	*(1×1)	1495,1521,1568 1570,1573,1618* 1784*
	Al	(1×1)	1521
		(1×1) Diffuse	1570
	Cl_2	Disordered	1660

†Organic overlayer structures and high-Miller-index surface structures are not included. See Table VII and Table X, respectively, for these structures.

TABLE I. Surface Structures on Substrates with One-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Cu	(1×1)	1568
	H_2O	Ordered	1573
		Disordered	1573
	Ni	Disordered	1568
InSb(110)	[clean]	*(1×1)	1181,1420,1888*
	Sn	Amorphous	1181
Te(10$\bar{1}$0)	[clean]	*(1×1)	1801*
ZnO(10$\bar{1}$0)	[clean]	*(1×1)	1104,1239,1612 1772*
	H_2O	Disordered	1104
	O_2	(1×1)–O	392
	Xe	Hexagonal	1026
		Disordered	1026
ZnO(11$\bar{2}$0)	[clean]	*(1×1)	1772*
ZnS(110)	[clean]	*(1×1)	1445*
ZnSe(110)	[clean]	*(1×1)	1478*
	O_2	ZnO(000$\bar{1}$)	642
ZnTe(110)	[clean]	*(1×1)	1378*,1495,1504

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry†

Substrate	Adsorbate	Surface Structure	Reference
Ag(110)	[clean]	*!(1×1)	707,888,1522,1534 1750!,1751,1872*
	Br_2	(2×1)–Br	888
		c(4×2)–Br	888
		AgBr	888
	C_2N_2	Disordered	407
	Cl_2	Adsorbed	732
	Cs	(1×2)	859,1534
		(1×3)	859,1534
	HCN	Disordered	407
	H_2O	Disordered	878
	H_2O+Li^+	Complex	1557
	H_2S	(3×2)–S	627
		c(10×2)–S	627
		(3×4)–S	627
	I_2	Pseudohexagonal–I	1145
		c(2×2)–I	1145
	K	(1×2)	1534
		(1×3)	1534
	Li	(1×2)	1534
	Na	(1×1)	489
	NO	Disordered	345
	O_2	!(2×1)–O	146,341,342,343 344,695,878,943 974,1027,1047 1140,1143,1160 1300,1690,1751!
		(1×2)–O	1376
		(3×1)–O	146,341,342,343 695,878,974,1143 1160,1300,1690
		(4×1)–O	146,341,342,878 974,1143,1300 1690
		(5×1)–O	146,341,695,1300
		(6×1)–O	146,341,1300
		(7×1)–O	146
		c(6×2)–O	974
	$O(a)+CO_2$	(2×2)	1143
	$O(a)+SO_2$	c(6×2)–SO_3	1027,1371
		(1×2)–SO_4 etc.	1371
	O_2+H_2O	(1×2)–OH	878
		(1×3)–OH	878
	SO_2	(1×2)–SO_2	1027,1371
		c(4×2)–SO_2	1027,1371
		(1×1)	1371
		$\begin{pmatrix} \frac{2}{3} & 1 \\ \frac{4}{3} & 0 \end{pmatrix}$–$SO_2$	1027
	Xe	Hexagonal Overlayer	159

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Al(110)	[clean]	(1×1)+(1×2)	965
		*(1×1)	1354,1409*,1464
			1498,1566*,1721*
	CO	Not Adsorbed	1273
	O_2	(331) facets	123
		(111) facets	122
		Disordered	709
Au(110)	[clean]	*(1×2)	754,1009,1098,1166
			1752*
		(1×2)+(1×1)	965
		(1×3)	754,1098
	Bi	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	498
		$\begin{pmatrix} 2 & 1 \\ -1 & 1 \end{pmatrix}$	498
		(2×1)	498
	H_2S	(1×2)–S	251
		c(4×2)–S	251
	Pb	(1×3)	444,495,683
		(1×1)	444,495,683
		(7×1)	444,495,683
		(7×3)	444,495,683
		(4×4)	444,495,683
C(10$\bar{1}$0)	[clean]	c(2×2/3)	1033
C(110),diamond	O_2	Not Adsorbed	164
	N_2	Not Adsorbed	164
	NH_3	Not Adsorbed	164
	H_2S	Not Adsorbed	164
CdTe(100)	[clean]	(3×1),(1×1),{110}f	1393
Co(10$\bar{1}$0)	O_2	(2×1)–O	1070
Co(11$\bar{2}$0)	[clean]	*(1×1)	1197,1768,1848*
	CO	(3×1)–CO	902
		Disordered	902
	H_2O	Disordered	1310
		(4×1)–O	1310
		Complicated	1310
Cr(110)	[clean]	(1×1)	1343
	CO	Disordered	1343
	Br_2	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	1016
		$\begin{pmatrix} 1 & \frac{1}{1+X} \\ -1 & \frac{2}{1+X} \end{pmatrix}$–Br $(0<X<1/3)$	1016
		$\begin{pmatrix} 1 & 1 \\ -2 & 2 \end{pmatrix}$–Br	1016

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	O_2	(3×1)-O	140
		(100) facets	140,256
		$Cr_2O_3(0001)$	140,256
		Cr_2O_3	1261
		Disordered	1261
Cu(110)	[clean]	*!(1×1)	725*,925,995,1023,1131 1135!,1136*,1436 1498,1723*
	Au	$\begin{pmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{3}{2} \end{pmatrix}$	479
		(1×2)	479
		(2×2)	479
		Complex Structures	479
	Br_2	c(2×2)	1557
	$Br(a)+H_2O$	(3×2)	1557
	C	Disordered	1695
	$C+O_2$	(2×1)	1695
	CO	Ordered 1D	26
		(2×3)-CO	26
		(2×1)-CO	255,876,1234
		c(5/4×2)	876
		c(1.3×2)-CO	1234
		Hexagonal Overlayer	255
	H_2	Not Adsorbed	7
	H_2O	Disordered	26
		Not Specified	1131
		c(2×2)-H_2O	1023,1178,1270
		c(2×2)	1557
		(2×1)-OH	1270
		(1×1)-H_2O	1178
	H_2S	c(2×3)-S	35
		Adsorbed	35
	I_2	!c(2×2)-I	572,1915!
		!c(2×2) Compressed	1915!
	Kr	c(2×8)-Kr	1304,1331
		Quasiperfect Hex.	1331
	N_2O	(2×1)-O	879
	$Ni(CO_4)+CO$	(1×1)+Disordered	1048
	O_2	!(2×1)-O	7,8,9,45,46,246 656,750,879,885 920,953,982,1053 1066,1076,1095 1257,1285,1695 1916!,1917!,1918!
		c(2×1)-O	1270
		Streaks along <110>	1023
		(1×1)-O	656,885
		(3×1)-O_2	885

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		c(6×2)–O	8,9,45,46,246,656 885,920,1066,1076 1095,1257,750,953 1285,1695
		(5×3)–O	8,115
		c(14×7)–O	1332
	O(a)+CO	Disordered	1066
	O(a)+H_2O	(2×1)–O,H_2O	1023
		c(2×2)–O,H_2O	1023
		(2×1)–H_2O	1270
		(1×1)–H_2O,OH	1270
		(2×1)–OH,O	1270
	Pb	$\begin{pmatrix} 1 & 1 \\ -1 & 1 \end{pmatrix}$	481,482
		(5×1)	481,482
		(4×1)	482
	Pd	(2×1)–Pd	726
		(1×1)–Pd	726
	Xe	c(2×2)–Xe	159,1331,1611
		Hexagonal Overlayer	159,1611
		Pseudo-Hexagonal	1331
Cu/Au(110)	[clean]	Streak	737
		(1×2)	737
		Complex Pattern	737
		c(3×1)	737
		(2×2)	737
Cu/Ni(110)	CO	(2×1)–CO	134
		(2×2)–CO	134
		(1×2)–CO	787
	H_2	(1×3)–H	787
	H_2S	c(2×2)–S	134
	O_2	(2×1)–O	134,872
		(2×2)–O	872
Cu(110)–Ni(1°)	O_2	(2×1)–O	1311
		c(6×2)–O	1311
Cu/Pd(110)	[clean]	(2×1)	737
Cu–25% Zn(110)	[clean]	(1×1)	1152
	O_2	Disordered	1152
Fe(110)	[clean]	*(1×1)	1015,1639*
	CO	$\begin{pmatrix} 3 & -2 \\ 0 & 4 \end{pmatrix}$–CO	346
		c(2×4)	810
		(1×2)	810
		c(2×2)	687
		(1×4)	687
		$\begin{pmatrix} 4 & 0 \\ -1 & 3 \end{pmatrix}$	687
	CO_2	c(2×2)	687
		(1×4)	687

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{bmatrix} 4 & 0 \\ -1 & 3 \end{bmatrix}$	687
	Fe_3O_4	Not Well Ordered	1189
	H_2	*(2×1)–H	177,1753*
		*(3×1)–2H	177,1753*
		(1×1)–H	177
		c(2×2)–H	687,1298
		(3×3)–6H	1298
		$\begin{bmatrix} 1 & -1 \\ 1 & 2 \end{bmatrix}$	687
	H_2S or S	(2×4)–S	114
		(1×2)–S	114
		*(2×2)–S	836,1000,1015,1608*
		c(3×1)–S	836
		c(18×3)–S	836
	K	Hexagonal Array	728
	$K+O_2$	c(4×2)	786
	N_2	$\begin{bmatrix} 3 & -2 \\ 0 & 4 \end{bmatrix}-N_2$	346
	NH_3	(2×2)	687
		Disordered	1686
		$\begin{bmatrix} 4 & 1 \\ -3 & 3 \end{bmatrix}$	687
		(2×2)–NH	1686
	O_2	c(2×2)–O	87,88,99
		(2×2)–O	1015
		c(3×1)–O	87,88,99
		(2×8)–O	98
		FeO(111)	87,88,99,269
		(2×1)–O	141
		(5×12)–O	1664
Fe/Cr(110)	O_2	Cr_2O_3(0001)	280
		Amorphous Oxide	279
Ge(110)	|clean|	c(8×10)	804,1683
		Ge(17,15,1)–(2×1)	804,1683
	H_2S	(10×5)–S	178
	O_2	Disordered	17,18
		(1×1)–O	17,18
GaAs(100)	|clean|	(2×4)	1085,1090,1274,1387
		(4×2)	1274
		c(4×4)	697,1085,1240 1387,1541
		(4×6)	697,1090,1213,1240 1377,1448,1541
		c(6×4)	697
		(1×1)	1213,1519
		(2×8)	1449
		c(2×8)	697,1090,1213,1240 1541

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		c(8×2)	697,1090,1213,1448 1541
		(8×2)–Ga	1519
		(1×2)	1448
		(1×6)	697,1541
	[laser process]	(1×1)+steps	1446
	Ag	c(8×2)	710
		c(2×8)	710
		c(4×4)	710
		c(6×6) [Multilayer]	1344
	Al	c(8×2)	710
		c(2×8)	710
		c(2×2) [Multilayer]	1344
	As_4	c(4×4)	1422
	As_4,Ga	(2×4)	1365
		(4×6)	1365
		c(8×2)	1365
		(4×1)	1365
		(3×1)	1365
	$Fe(CO)_5$	$(1/\sqrt{2}\times1/\sqrt{2})R45°$ [Multilayer]	1377
	Bi	(1×1)–Bi	1491
		(1×2)–Bi	1491
		(3×1)–Bi	1491
		(8×2)–Bi	1491
	Ge	(1×2)–Ge	1213
		(1×2)+(2×1)	1213
	H_2	(1×1)	1541
	H_2S	c(2×8)–H_2S	589
		(2×1)	589
	HCl,H_2O	(1×1)	1518
	Pb	(1×4)–Pb	1387
	Pb,As_4	(1×2)–Pb	1387
	Sn	(1×3)–Sn	1387
	Sn	(1×2)–Sn	1387
GaAs(100)–As rich	[clean]	c(4×4)	1214,1524
GaAs(100)–Ga rich	[clean]	(4×6)	1214,1524
GaP(100)	[clean]	(4×2)	694
	Cs	(1×4)–Cs	694
		(7×1)–Cs	694
		(1×4)–Cs	694
	PH_3	(1×2)	694
	Si	(2×1)	1554
Ge(110)	H_2S	(10×5)–S	178
	O_2	Disordered	17,18
		(1×1)–0	17,18
InP(100)	[clean]	(4×2)	1170,1384
	[laser annealed]	(1×1)	1170,1384
	[laser annealed]	(1×1)+steps	1446
	Sb	*(1×1)	1919*,1920*
InSb(001)	[clean]	c(2×8)	1159,1421
	Sn	α–Sn(001)–(2×1)	1159
Ir(110)	[clean]	*(1×2)	701*,1321,1665 1787,1875*
		*(1×1)	1786*

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	CO	(2×2)–CO	347,348
		(4×2)–CO	348
	H_2	(1×2)	830
		Adsorbed	347
	H_2O	Adsorbed	615
	H_2S	*(2×2)–2S	715,1875*
		(1×2)–S	715
		c(2×4)–S	715
	N_2	(1×2)	678
		(2×2)–N_2	678
		Not Adsorbed	347
	NO	Disordered	677
		Streaks	677
	O_2	(1×2)–O	347,1687
		(1×4)–Oxide	571,706
		Disordered	571
		(2×2)–O	571,706
		*c(2×2)–O	571,706,1788*
		(3×2)	706
		(1×1)–O	1676,1687
LaB_6(110)	[clean]	c(2×2)	775,1328
	O_2	(1×1)–O	349,1328
Mo(110)	[clean]	*(1×1)	1634*
	Al	Hexagonal	515
	Au	Disordered	1681
	C	(4×6)–C	1250
	Cl_2	(2×1)–Cl	1250
		(1×1)–Cl	1250
		(1×2)–Cl	1250
		(1×3)–Cl	1250
	CO	(1×1)–CO	62,100
		c(2×2)–CO	94
		Disordered	406
	CO_2	Disordered	94
	Cs	Hexagonal	512
	H_2	Adsorbed	100
	H_2S	(2×2)–S	351
		c(2×2)–S	351
		(1×1)–S	351
		c(1×3)–S	351
		c(1×5)–S	351
		(1×3)–S	351
		c(1×7)–S	351
		(1×4)–S	351
		(1×5)–S	351
		c(1×11)–S	351
		$\begin{pmatrix} 2 & 2 \\ -1 & 1 \end{pmatrix}$–S	351
	K	Hexagonal	512
	KCl	Disordered	781
	N_2	(1×1)–N	62
	Na	No Ordered Structure	512

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	O_2	(2×2)–O	62,63,100,1154
		(2×1)–O	62,63,100
		(1×1)–O	62,63
		Disordered	350
		Complex	1154
	Rb	Hexagonal	512
MoO_3(010)	[clean]	(1×1)	922,1128
	H_2	3D–MoO_2	922
Na(110)	[clean]	*(1×1)	1754*,1755*
	O_2	Na_2O(111)	352*
$Na_{2/3}WO_3$(110)	[clean]	(3×1)	906
Nb(110)	CO	Disordered	101
		(3×1)–O	101
	H_2	(1×1)–H	111
	O_2	(3×1)–O	101
		NbO(111)	192
		NbO(110)	192
		NbO(220)	192
		Oxide	101
		Complex Pattern	1688
	Sn	Disordered	505
		(3×1)	505
Ni(110)	[clean]	(2×1)	882
		*!(1×1)	890,1061!,1459* 1468,1469,1470 1756*,1757*,1758!,1853!
	C	c(4×5)–C	1198
	Cl_2	c(2×2)–Cl	1341
		(10×2)–Cl Diffuse	1341
	CO	(1×1)–CO	2,94
		Adsorbed	198
		c(2×1)–CO	353,356,359,645
		(2×1)–CO	356,357,358
		c(2×2)–CO	359,645
		(4×2)–CO	359,645
	CO+O_2	(3×1)–CO+O_2	91
	Cs	Disordered	455
	D_2	(2×1)–D	869,944,1097
		(1×2)–D	869,944,1097
	H_2	(1×2)–H	59,81,94,110,198 203,353,360,867 941,927,1031,1074,1527,1673
		(2×1)–2H	867
		(2×1)–H	941,890,1031,1074 1527
		c(2×6)–H	890,1031
		(2×6)–H	1074
		(2×3) with streaks	1031
		c(2×4)–H	1031
	H_2O	(2×1)–H_2O	110
	H_2S (or S)	*!c(2×2)–S	36,198,205,294 1079,1142!,1370 1759*,1853!
		*(2×2)–S	1079,1867*

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		(3×2)-S	36
		(1×1)-S	1142
	H_2Se	!c(2×2)-Se	137,1708!
	K	Disordered	455
	N_2	(2×1)-N_2	1074,1309
		(2/3×1/3)-N_2	1074
		(2×3)-N	759
		c(2×4)-N_2	759
	N_2^+	Disordered	1290
		(2×3)-N	1290
	Na	Disordered	455,458,460
		Hexagonal	455,458,460
	NH_3	(1×1)-NH_3	840,880,1560
		(4×2)-NH_3	840
		c(6×2)-NH_3	840
		c(4×2)-NH_3	840,880
		(3×2)-NH	1107
	NH_3+e^-	c(2×2)-NH_2	840
		(2×3)-N	840
	NO	(2×3)-N	361
		(2×1)-O	361
	O_2	!(2×1)-O	2,3,51,57,83,89 91,92,99,198,353 354,355,729!,912,968 1069,1074,1140 1164,1168,1290 1292,1370,1437
		(3×1)-O	2,51,83,89,91,92 94,198,353,354 355,912,1011,1041 1437
		(2×1)+(3×1)-O	968
		(5×1)-O	2,89
		(9×4)-O	51,354,355,1437
		Disordered	1437
		NiO(100)	6,51,83,91,198, 354,355
		Disordered Oxide	1437
	O_2+H_2O	(2×1)-OH	1011
	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	471
		(3×1)	471
		(4×1)	471
		(5×1)	471
	Se	c(2×2)-Se	1370
	Te	c(2×2)-Te	1370
	Yb	(2×1)-Yb	844
NiAl(110)	[clean]	*(1×1)	1771*
Ni-25% Fe(110)	H_2S.H_2	(2×3)-S	1121
Ni_4Mo(101)	[clean]	Ordered	1115

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Pd(110)	[clean]	*(1×1)	1760*
	Cl_2	c(16×2)–Cl	1341
	CO	(5×2)–CO	95
		(2×1)–CO	95,209
		(4×2)–CO	209
		c(2×2)–CO	209
		c(4×2)–CO	1359
		(4×1)–CO	1359
		c(4×2)–CO Imperfect	1251
	Cs	*(1×2)+Disordered Cs	1760*
	H_2	(1×2)–H	212,1173
		(2×1)–H	1173
	H_2S	(2×3)	625
		c(2×2)	625
		c(8×2)	625
		(3×2)	625
	Na	*(1×2)+Disordered Na	1760*
	O_2	(1×3)–O	95
		(1×2)–O	95
		c(2×4)–O	95
	Xe	Hexagonal	743
Pt(110)	[clean]	!(1×2)	960,1062,1080,1166,1187 1271,1279,1297 1761!,1890
		(1×1)	1279
	C_2N_2	(1×1)	407,435
	C_3O_2	(1×1)–C_3O_2	365
	Cl_2	(1×2)–Cl	1341
		(1×1)–Cl	1341
		(2×1)–Cl Diffuse	1341
	CO	(2×1)–CO	366,981,1271 1279,1297,1360
		(1×1)–CO	139,364,763,1271 1279,1297,1360
		(1×2)–CO	1360
		(1×1)+(1×2)	1297,1360
		c(8×4)–CO	1271,1279,1360
	CO+NO	(1×1)–CO+NO	364
	H_2	(1×1)	1279
		(1×2)	1279
	H_2S	c(2×6)–S	247,367,368,1114
		(2×3)–S	247,367,368,1114
		(4×3)–S	247,367,368,1114 1116
		c(2×4)–S	247,367,368,1114
		(4×4)–S	247,367,1114
	HCN	$\begin{pmatrix} 1 & \frac{2}{3} \\ -1 & \frac{2}{3} \end{pmatrix}$	434
		c(2×4)	434
		(1×1)	434

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	HNCO	(2×2)–NCO	657
		(1×2)–NCO	657
	NO	(1×1)–NO	222,364
		(2×1)–NO	614
		c(4×8)–NO	614
		Disordered	614
	O_2	(2×1)–O	11,363
		(4×2)–O	11
		Adsorbed	362
		c(2×2)–O	363
		PtO(100)	363
		(1×1)–CO	139,364
		(1×3)	763
		(1×5)	763
		(1×7)	763
		Satellite Spots	1279
Pt–2% Cu(110)	[clean]	(1×3)	1062
	CO	(1×1)–CO	1063
Re(10$\bar{1}$0)	[clean]	*(1×1)	584*
	Ba	c(2×2)	1591
	Mg	(1×3)	1675
Re(11$\bar{2}$0)	after NH_3 synthesis	(1×1)	977
Rh(110)	[clean]	*(1×1)	1800*
	CO	(2×1)–CO	369
		c(2×2)–C	369
		Disordered	569
	H_2S	*c(2×2)–S	769*
	NO	Disordered	569,791
		(2×2)–N,O	569,791
		(2×1)–N,O	569,791
	O_2	Disordered	96,97
		c(2×4)–O	96,97
		c(2×8)–O	96,97
		(2×2)–O	96,97
		(2×3)–O	96,97
		(1×2)–O	96,97
		(1×3)–O	96,97
	S or H_2S	*c(2×2)–S	769*,1473
Ru(101)	CO	$\begin{pmatrix}1 & 1\\ 3 & 0\end{pmatrix}$–CO	372
		$\begin{pmatrix}0 & 1\\ 2 & 0\end{pmatrix}$–C	372
	NO	Disordered	373
	O_2	$\begin{pmatrix}1 & 1\\ 3 & 0\end{pmatrix}$–O	374
		$\begin{pmatrix}2 & 1\\ 5 & 0\end{pmatrix}$–O	374
		$\begin{pmatrix}4 & 1\\ 9 & 0\end{pmatrix}$–O	374

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ru(10$\bar{1}$0)	Cl_2	(1×1)–Cl	1052
		(2×3)–Cl	1052
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$–Cl	1052
		$\begin{pmatrix} 2 & 0 \\ -1 & 4 \end{pmatrix}$–Cl	1052
		(2×1)–Cl	1052
	CO	Disordered	371
	H_2	Not Adsorbed	371
	N_2	Not Adsorbed	371
	NO	c(4×2)–N+O	370,371
		(2×1)–N+O	370,371
		(2×1)–O	371
		c(4×2)–O	371
		c(2×6)–O	370
		(7×1)–O	370
		c(4×8)–O	370
		(2×1)–N	371
		c(4×2)–N	371
	O_2	c(4×2)–O	370,371
		(2×1)–O	370,371
		c(2×6)–O	370
		(7×1)–O	370
		c(4×8)–O	370
Si(110)	[clean]	(4×5)	803,1685
		(2×1)	803,1685
		(5×1)	803,1685
	Bi	(2×3)–Bi	659
		Disordered	659
	H_2	(1×1)–H	375
	H_2O	Adsorbed	903
	Si,laser	(1×2)	1392
SnO_2(101)	[clean]	(1×1)	1183
$SrTiO_3$(110)	[clean]	(3×2)	1490
Ta(110)	Al	Hexagonal	508,509
		Square	508,509
	Cl_2	(1×1)–Cl	1180
		(1×2)–Cl	1180
		c(1×5)–Cl	1180
		c(1×7)–Cl	1180
		Streak <001>	1180
		Complicated	1180
	CO	Disordered	101,102
		(3×1)–O	101,102
	H_2	(1×1)–H	102
	I_2	$\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$–I	1180
		(1×1)+c(1×3)–I	1180
		(1×1) with ring	1180

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		c(4×4)–I	1180
	N_2	Not Adsorbed	101
	O_2	(3×1)–O	101,102
		Oxide	101,102
TiO_2(100)	[clean]	(011)–(2×1) facet	1318,1615
		(114)facet	1318
	H_2O	Disordered	376
	O_2	Disordered	376
TiO_2(110)	[clean]	(1×1)	1615
V(110)	[clean]	*(1×1)	649*,1498,1762*
	CO	Disordered	101
		(3×1)–O	101
	O_2	(3×1)–O	101
V_6O_{13}(001)	K	No Superstructure	1186
W(110)	[clean]	*(1×1)	1123,1247,1763*
	Ag	Hexagonal Structures	546,547
		Ag(111)	1151
	Au	Hexagonal Structures	546,548
	Ba	Disordered Hexagonal	533–535
		Hexagonal	533–535
		$\begin{pmatrix} 2 & 2 \\ 0 & 6 \end{pmatrix}$	533–535
		$\begin{pmatrix} 2 & 2 \\ 0 & 5 \end{pmatrix}$	533–535
		$\begin{pmatrix} 3 & 3 \\ 1 & 5 \end{pmatrix}$	533–535
		Hexagonal Compact	533–535
	Be	(1×9)	529
		(1×1)	529
		$\begin{pmatrix} 9 & 0 \\ -1 & 1 \end{pmatrix}$	529
	Cl_2	(5×2)–Cl	796
	CO	Disordered	109
		c(9×5)–CO	109
		(1×1)–CO	379
		c(2×2)–CO	379
		(2×7)–CO	389
		c(4×1)–CO	389
		(3×1)–CO	389
		(4×1)–CO	389
		(5×1)–CO	389,390
		(2×1)–C+O	389,390
		c(9×5)–C+O	389
	$CO+O_2$	c(11×5)–$CO+O_2$	93
	Cs	Disordered Hexagonal	523,527,528
		Hexagonal	523,527,528,1677
	Cu	Hexagonal	543–545
		Cu(111)	1151

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Fe	3-Dimensional Crystals	451
		Fe(110)	1325
		(1×1)	1325
	H_2 or D_2	(2×1)-H	136,1516,1674
		(1×2)-H	672
		(2×2)-H	1516,1674
		(1×1)-H	1516
		Ordered	1438
		(2×2)-H_2	1516
		(2×1)-H_2	1516
	I_2	(2×2)-I	391
		(2×1)-I	391
	Li	$\begin{pmatrix} 1 & 5 \\ -2 & 2 \end{pmatrix}$	517–519
		(2×2)	517–519
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	517–519
		(2×3)-Li	1269
		c(2×2)-Li	1269
		c(3×1)-Li	1269
		c(1×1)-Li	1269
	N_2	(2×2)-N	758
	Na	$\begin{pmatrix} 1 & 5 \\ -2 & 2 \end{pmatrix}$	445,446
		(2×2)	445,446
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	445,446
		$\begin{pmatrix} 1 & 1 \\ 0 & 8 \end{pmatrix}$	445,446
		$\begin{pmatrix} 1 & 1 \\ 0 & 5 \end{pmatrix}$	445,446
		Hexagonal	445,446
	Ni	(1×1)-Ni	970
		(8×2)-Ni	970
		(7×2)-Ni	970
	NO	(1×1) streaked	661
		c(11×5)	661,799
		(2×2)	661,799
	O_2	*(2×1)-O	57,103,377–385,386*,387 599,699,1277,1418 1587,1651
		c(2×2)-O	104
		(2×2)-O	104,387,599,699
		(1×1)-O	104
		c(14×7)-O	57,103,104,628
		c(21×7)-O	104
		c(48×16)-O	104

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$WO_3(100)$	388
		$WO_3(111)$	388
	Pd	(1×3)	542
		Hexagonal	542
	Pd(1ML)+CO	Not Adsorbed	1218
	Pd(2.2ML)+O_2	(2×2)–O	1218
	Pb	Split $\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	551,552
		$\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	551,552
	S_2	(2×2)–S	1246
		(7×2)–S	1246
		Rotated Structure	1246
		(1×N)–S (N>=3)	1246
	Sb	$\begin{pmatrix} 1 & 1 \\ 0 & 4 \end{pmatrix}$	553,555
		$\begin{pmatrix} 2 & 0 \\ -1 & 1 \end{pmatrix}$	553,555
		$\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	553,555
		$\begin{pmatrix} 4 & 0 \\ -1 & 1 \end{pmatrix}$	553,555
	Sc	$\begin{pmatrix} 1 & 1 \\ 0 & 3 \end{pmatrix}$	536–538
		$\begin{pmatrix} 2 & 2 \\ 0 & 8 \end{pmatrix}$	536–538
	Se	(5×2)–Se	1228
		(1×3)–Se	1228
		Complex	1228
	Sr	$\begin{pmatrix} 3 & 3 \\ -2 & 5 \end{pmatrix}$	530
		$\begin{pmatrix} 2 & 2 \\ 0 & 6 \end{pmatrix}$	530
		$\begin{pmatrix} 2 & 2 \\ 1 & 6 \end{pmatrix}$	530
		$\begin{pmatrix} 1 & 0 \\ 0 & 3 \end{pmatrix}$	530
		Hexagonal	530
	Te	(4×2)–Te	1280
		(20×2)–Te	1280
		(17×2)–Te	1280
		(5×2)–Te	1280
		(22×2)–Te	1280

TABLE II. Surface Structures on Substrates with Two-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	W	Ring Pattern	1623
	WO_2	(2×2)	1501
	Xe	(2×2)–Xe	713
		Disordered	713
	Y	Hexagonal	539,540
ZnSe(100)	[clean]	$(\sqrt{2}\times\sqrt{2})R45°$	1393
		(5×1)	1393
ZnTe(100)	[clean]	(1×3),(1×1)+{110}f	1393
	Au	(1×1)–Au	1188

†Organic overlayer structures are not included. See Table VII for these structures.

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry†

Substrate	Adsorbate	Surface Structure	Reference
Ag(111)	[clean]	*(1×1)	975,1894*,1895*,1896*
	Al	Disordered	491
	Au	*(1×1)	491,1355,1825* 1826
	Bi	Disordered	491
	Br_2	$(\sqrt{3}\times\sqrt{3})R30°$–Br	155
		(3×3)–Br	155
	Cd	No Condensation	491
	Cl_2	(1×1)+Disordered	1050
		$(\sqrt{3}\times\sqrt{3})R30°$–Cl	151,1050
		(10×10)–Cl	151
		AgCl(111)	152,732,1050
	Co	Disordered	491
	$CO+O_2$	$(2\times\sqrt{3})$–$(CO+O_2)$	27
	Cr	Disordered	491
	Cu	Hexagonal Overlayer	1822–1824
	H_2O	Disordered	1034
	H_2S	(4×4)–S	627
		$\begin{pmatrix} 3 & 2 \\ -2 & 1 \end{pmatrix}$–S	627
	I_2	*$(\sqrt{3}\times\sqrt{3})R30°$–I	145,149,150,1145 1225*,1259,1440
		Hexagonal Overlayer	1145
	K	Hexagonal Overlayer	1345
	Kr	Hexagonal Overlayer	156
	Mg	Disordered	491
	Na	(1×1)	488
	Ni	Hexagonal Overlayer	491,1821
	NO	Disordered	163
	O_2	(2×2)–O	1
		$(\sqrt{3}\times\sqrt{3})R30°$–O	1
		Not Adsorbed	146
		(4×4)–O	147,148
	Pb	$(\sqrt{3}\times\sqrt{3})R30°$–Pb	975
		Pb(111)	975
		Hexagonal Overlayer	491,1827
	Pd	(1×1)	1463
		Disordered	491
	Rb	(1×1)–Rb	490,705
		(9×9)	705
	S_2	$(\sqrt{39}\times\sqrt{39})R16.1°$–S	714
		$(\sqrt{7}\times\sqrt{7})R10.9°$ of γ–$Ag_2S(111)$	714
	Sb	Disordered	491
	Sn	Disordered	491
	Tl	Hexagonal Overlayer	491
	Xe	Hexagonal Overlayer	156,157,158,159 160
		*Incommensurate	1599*,1845*
	Zn	No Condensation	491

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ag(111)–Rb dosed	O_2	$(2\sqrt{3}\times 2\sqrt{3})R30°$–Rb/O	653
		(4×4)–Rb/O	653
		Complex Structures	653
		(9×9)–Rb/O	653
Al(111)	[clean]	*(1×1)	863,951,1141*,1354,1467*
			1472*,1498,1640
	Ag	Ag–Al(0001)	1161
	CO	Disordered	1175
		Not Adsorbed	1273
	Cu	(1×1)	863
		Disordered [Multilayer]	863
		Cu(111) [Multilayer]	863
	H_2O	Disordered	1157
	Mn	$\begin{bmatrix} 6 & 0 \\ -1 & 2 \end{bmatrix}$	502
		Hexagonal rotated ± 9°	502
	Na	$\begin{bmatrix} 1 & 1 \\ -1 & 2 \end{bmatrix}$	500
		(2×1)	500
	Ni	(1×1)	1680
		$\begin{bmatrix} 1 & 1 \\ -1 & 2 \end{bmatrix}$	1839
	O_2	(4×4)–O	123
		*!(1×1)–O	638,709,756,951,1141*
			1397,1467*,1621
			1637,1774!,1775!
		Oxide-like	1141
	Pb	Hexagonal rotated ± 9°	504
		Hexagonal Overlayer	1060
	Pd	Hexagonal Overlayer	1682
		$(\sqrt{3}\times\sqrt{3})R30°$–Pd	1661
	Sn	Hexagonal Rotated ± 9°	504
		Hexagonal Overlayer	1060,1682
	Tl	$(\sqrt{3}\times\sqrt{3})R30°$–Tl	1661
Au(111)	[clean]	(23×1)	861,1146,1558,1889
		(5×1)	1146
	Ag	(1×1)	491,1825
		fcc(111)	1689
	Ag,Air	$Ag_2O(110)$–(2×1)	997
	Bi	$\begin{bmatrix} 10 & 10 \\ -10 & 20 \end{bmatrix}$	498
		(2×2)	924
	Cl_2	(1×1)–Cl	647
	Cr	Hexagonal	493
	Cu	$(\sqrt{3}\times\sqrt{3})R30°$–Cu	861,1558,1582
		(1×1)	1558

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		Extra Lines(RHEED)	1836,1837
	Fe	(1×1)	1828,1830–1832
	O_2	Oxide	161
		Not Adsorbed	162
		Adsorbed	162
	Pb	Hexagonal Rotated ± 5°	444,495
		$(\sqrt{3}\times\sqrt{3})R30°$	924
		(1×1)	683
	Pd	(1×1)	1807,1834
	Pt	(1×1)	1835
	Si	(2×2)–AuSi	1622
		(3×3)–AuSi	1622
		Hexagonal Silicide	1622
Be(0001)	[clean]	*(1×1)	911,1900*,1901*
	CO	Disordered	22
	H_2	Not Adsorbed	22
	N_2	Not Adsorbed	22
	O_2	Disordered	22
		BeO(0001)–(1×1)	911
		BeO(0001)–(2×2)	911
Bi(0001)	O_2	$(\sqrt{3}\times\sqrt{3})R30°$	576,1065,1288
		(1×1)	576
		Coincidence Lattice	576,1065
		BiO	1288
	O_2+K	$(\sqrt{3}\times\sqrt{3})R30°$+BiO(0001)layer	1288
	Cl_2	(1×1)–Cl	1242
		$(2\sqrt{3}\times2\sqrt{3})R30°-BiCl_3$	1242
		(4×4)	1242
C(111), diamond	[clean]	(2×2)	820
		(2×1)	820
		*(1×1)	1551*
	H_2 (or D_2)	(1×1)–H(or D)	30,1386,1697
	H_2S	Not Adsorbed	164
	N_2	Not Adsorbed	164
	NH_3	Not Adsorbed	164
	O_2	Adsorbed	16
		Not Adsorbed	164
	P	$(\sqrt{3}\times\sqrt{3})R30°$–P	30
C(0001), graphite	[clean]	"(2×2)"	1190
		*(1×1)	1373,1439*,1846*
	Ar	$(\sqrt{3}\times\sqrt{3})R30°$–Ar	720,960
		*Incommensurate	1882,1903*
	Ar+Xe	$(\sqrt{3}\times\sqrt{3})R30°$–Ar,Xe	1193
	CF_4	$(2\times2)-CF_4$	1192,1194
		Close to (2×2)	1404
	CO	$(\sqrt{3}\times\sqrt{3})R30°$–CO	884
		$(2\sqrt{3}\times2\sqrt{3})R30°$–CO	889
		$(2\sqrt{3}\times\sqrt{3})R30°$ [Herringbone]	884
		Triangular Incommensurate (2×2)	884

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	H_2	$(\sqrt{3}\times\sqrt{3})R30°-H_2$	1283
		(2×2)	1373
		$(\sqrt{3}\times\sqrt{3})R30°$	1373
	K (intercalated)	*Disordered	1847*
	KOH	Disordered	1083
	Kr	!$(\sqrt{3}\times\sqrt{3})R30°$–Kr	166,167,174,721 828,960,1616,1904!
		Incommensurate	1413,1616
		Disordered	1413
	N_2	$(2\sqrt{3}\times2\sqrt{3})R30°-N_2$	889
		$(\sqrt{3}\times\sqrt{3})R30°$	1064,1190,1512
		$(\sqrt{3}\times\sqrt{3})R30°+(2\times1)$	1435
		Commensurate	1190,1883
		Incommensurate	1443,1883
	NaOH	1/2 Order Ring	1083
	Ne	Incommensurate	629
		$(\sqrt{3}\times\sqrt{3})R30°$ rotated by $\pm17°$	629,960
		Ordered	1338
	NO	Incommensurate	1602
	O_2	Triangular	1883
		Centered-Parallelogram–O_2	1425,1883
		$(\sqrt{3}\times\sqrt{3})R30°-O_2$	1200
		Physisorbed	1411
	Xe	$(\sqrt{3}\times\sqrt{3})R30°$–Xe	165,618,960,1038,1201
Cd(0001)	[clean]	(1×1)	1902
CdS(0001)	O_2	Disordered	25
CdTe(111)	[clean]	(2×2)	1393
CdTe($\overline{111}$)	[clean]	$(1\times1),(1\times1)+\{110\}f$	1393
Co(0001)	[clean]	*(1×1)	1130,1580,1613*
	CO	$(\sqrt{3}\times\sqrt{3})R30°$–CO	168,1130,1362
		$(2\sqrt{3}\times2\sqrt{3})R30°$–CO	1130,1362
		c(4×2)–CO	1362,1581
		$(\sqrt{7}/2\times\sqrt{7}/2)R19.10°$–CO	1362
		Hexagonal Overlayer	168
		$(\sqrt{7/3}\times\sqrt{7/3})R10.9°$–CO	1130
	H_2O	Disordered	1310
	NO	$(\sqrt{39}\times\sqrt{39})R16.1°$–N,O	788
	O_2	No Superstructure	1235
Co(111)	[clean]	*(1×1)	1613*
CoO(111)	[clean]	*(1×1)	1769*
Cr(111)	Ag	(8×8)	46
	Au	$\begin{pmatrix} \frac{2}{3} & 3 \\ \frac{-2}{3} & \frac{4}{3} \end{pmatrix}$	52
	Bi	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	61

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 2 & -1 \\ 0 & 2 \end{pmatrix}$	61
		$\begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix}$	61
	Fe	(1×1)	39
	Ni	(1×1)	43,44
	O_2	$(\sqrt{3}\times\sqrt{3})R30°$–O	169
	Pb	(4×4)	55,58
	Sn	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	54
Cu(111)	[clean]	*(1×1)	1101,1408*,1419 1462,1510,1538 1635
	Ag	(8×8)	477
		3 Dimensional Crystals	1813,1815–1818
		(1×1)	1526
	Au	$\begin{pmatrix} \frac{2}{3} & \frac{2}{3} \\ -\frac{2}{3} & \frac{4}{3} \end{pmatrix}$	479
		(2×2)	479
		3 Dimensional crystals	1815,1819
	Bi	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	487
		$\begin{pmatrix} 2 & -1 \\ 0 & 2 \end{pmatrix}$	487
		$\begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix}$	487
	C_2N_2	Disordered	666
	C	Disordered	840,1695
	Cl_2	$(\sqrt{3}\times\sqrt{3})R30°$–Cl	151,1102
		$(6\sqrt{3}\times6\sqrt{3})R30°$–Cl	151
		$(12\sqrt{3}\times12\sqrt{3})R30°$–Cl	151
		$(4\sqrt{7}\times4\sqrt{7})R19.2°$–Cl	151
	CO	Not Adsorbed	26
		$(\sqrt{3}\times\sqrt{3})R30°$	172,173,590,1306
		(1.5×1.5)R18°	590
		(1.39×1.39)	591,592,593
		$(\sqrt{7/3}\times\sqrt{7/3})R49.1°$	172,173
		(3/2×3/2)	173
	Co	(1×1)–Co	1299

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Cs	*(2×2)–Cs	711,1430*
	Fe	(1×1)	474
	H_2	Not Adsorbed	7
	H_2S	$(\sqrt{3}\times\sqrt{3})R30°$–S	35
		Adsorbed	35
	HNCO	Disordered	624
	I_2	!$(\sqrt{3}\times\sqrt{3})R30°$–I	574,1259,1779!
	Na	(2×2)–Na	1571
	Ni	*(1×1)–Ni	475,476,1466* 1813
	$Ni(CO)_4$+CO	(1×1)+Disordered	1048
	O_2	Disordered	7,170,171,1095 1244
		(7×7)–O	7,8
		$(\sqrt{3}\times\sqrt{3})R30°$–O	7,8,1286
		(2×2)–O	7,8,115
		(3×3)–O	8
		(11×5)R5°–O	9
		(2×2)R30°–O	115,119
		$\begin{pmatrix} 3 & 2 \\ -1 & 2 \end{pmatrix}$–O	1066
		Hexagonal	246
	O_2+HCN	Disordered	1244
	O(a)+CO	Disordered	1066
	Pb	(4×4)	481,484
	Pd	(1×1)	726,11441538
	Sn	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	480
	Te	!$(2\sqrt{3}\times\sqrt{3})R30°$	1905!
	Xe	$(\sqrt{3}\times\sqrt{3})R30°$–Xe	159
Cu/Al(111)	[clean]	(1×1)	813
		$(\sqrt{3}\times\sqrt{3})R30°$	813
Cu–5.7% Al(111)	[clean]	(1×1)	813
Cu–10% Al(111)	[clean]	(1×1)	1303
		$(\sqrt{3}\times\sqrt{3})R30°$–Al	1303
Cu–11% Al(111)	[clean]	(1×1)	1506
Cu–12.5% Al(111)	[clean]	$(\sqrt{3}\times\sqrt{3})R30°$	813
Cu–16% Al(111)	[clean]	*$(\sqrt{3}\times\sqrt{3})R30°$	1699*
Cu/Au($1\bar{1}1$)	[clean]	$(2/3\sqrt{3}\times 2/3\sqrt{3})R30°$	737
		(2×2)	737
Cu/Ni(111)	CO	Disordered	173,734
Cu/Pd($1\bar{1}1$)	[clean]	(1×1)	737
Cu–25% Zn(111)	[clean]	(1×1)	1152
	O_2	Disordered	1152

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Fe(111)	[clean]	*(1×1)	1700*,1701*
	CO	Disordered	1004
		(1×1)	687
		(5×5)	687
		(3×3)	687
	CO_2	(1×1)	687
		(5×5)	687
		(3×3)	687
	H_2	Adsorbed	177
		(1×1)	687
	H_2O	(1×1)–H_2O	1588
	K	(3×3)–K	665,1350
	N_2	c(2×2)–N	1350
		(3×3)–N	1350
	N(a)+K	(3×3)–K,N	1350
	NH_3	Disordered	176,687
		(3×3)–N	176,687
		(5×5)	687
		$(\sqrt{19}\times\sqrt{19})R23.4°$–N	176
		$(\sqrt{21}\times\sqrt{21})R10.9°$–N	176,687
	O_2	(6×6)–O	175
		(5×5)–O	175
		(4×4)–O	175
		$(2\sqrt{7}\times2\sqrt{7})R19.1°$–O	175
		$(2\sqrt{3}\times2\sqrt{3})R30°$–O	175
	S	(1×1)–S	1577,1655
Fe–18% Cr–12% Ni(111)	[clean]	(1×1)	1249
	I_2	$(\sqrt{3}\times\sqrt{3})R30°$–I	1249
	H_2O	Ordered	1249
	O_2	Ordered	1249
	I(a)+H_2O	Oxide Not Formed	1249
	H_2O(a)+I_2	Adsorbed	1249
α–Fe_2O_3(001)	[clean]	(2×2)	1118
		Incommensurate	1118
		$(\sqrt{3}\times\sqrt{3})R30°$	1118
FeTi(111)	[clean]	(1×1)	1241
GaAs(111)	[clean]	c(8×2)	1170
	Laser-annealed	(1×1)	1170
		*(2×2)	1090,1702*
GaAs$(\overline{111})$	[clean]	(1×1)	1090
GaAs$(\overline{111})$	$Fe(CO)_5$	Facet{100}	1377
GaAs$(\overline{111})$–As rich	[clean]	(2×2)	1524,1541
	H_2	(1×1)	1541
GaAs$(\overline{111})$–Ga rich	[clean]	$(\sqrt{19}\times\sqrt{19})R23.4°$	1541
		(1×1)	1541
GaP(111)	[clean]	*(2×2)	819,1703*

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ge(111)	[clean]	(2×8)	804,996,1046,1075
		(2×1)	1046,1075,1086 1296,1374,1683
		(1×1)	1075,1296,1374
		c(2×8)	1550
	laser process	(1×1)	1492
	Al	(2×1)	1550
	Au	$(\sqrt{3}\times\sqrt{3})R30^\circ$-Au	1223
	Cl_2 or Cl	(7×7)-Cl	1088
		!(1×1)-Cl	1704!
	H_2O	(1×1)-H_2O	121,179,1662
	H_2S	(2×2)-S	37
		(2×1)-S	178
	H_2Se	(2×2)-Se	37
	I_2 or I	(1×1)-I	19,1088
	In	$(n\times2\sqrt{3})$-In,n=10–13	802
		$(4\sqrt{3}\times4\sqrt{3})R30^\circ$-In	802
		$(\sqrt{31}\times\sqrt{31})R(\pm9^\circ)$-In	802
		$(\sqrt{61}\times\sqrt{61})R(30\pm4^\circ)$-In	802
		(4.3×4.3)-In	802
		(4×4)-In	802
	O_2	Disordered	17,18
		(1×1)	19,21
	P	(1×1)-P	19
	Pb	$(\sqrt{3}\times\sqrt{3})R30^\circ$-Pb	1075,1400,1474
		(1×1)-Pb	1075,1474
	S	$(\sqrt{3}\times\sqrt{3})R30^\circ$	1589
		(3×3)	1589
		(2×8)-Ge_2S	1589
	Si	(1×1) with streaks	1029
	Sn	(2×8)-Sn	639
		$(\sqrt{3}\times\sqrt{3})R30^\circ$-Sn	639,1049
		(7×7)-Sn	639,1049
		(5×5)-Sn	639,1049
		$(3\times2\sqrt{3})$-Sn	996
		$(\sqrt{91}\times\sqrt{3})$-Sn	996
		(1×1)-Sn	996
	Te	(2×2)-Te	1088
InSb(111)	[clean]	!(2×2)	849,852,1906!
	a-Sn	a-Sn(111) (1×1) [Multi Layer]	849
InSb($\overline{111}$)	[clean]	(3×3)	849,852
	a-Sn	a-Sn(111) (1×1) [Multi Layer]	849
Ir(111)	[clean]	*(1×1)	1705*
	Au	(1×1)	453
	CO	$(\sqrt{3}\times\sqrt{3})R30^\circ$-CO	124,180,182,183 185,186
		$(2\sqrt{3}\times2\sqrt{3})R30^\circ$-CO	180,182,183,185 186
	Cr	Hexagonal	453
	H_2	Adsorbed	187
	H_2O	Not Adsorbed	182
	H_2S	*$(\sqrt{3}\times\sqrt{3})R30^\circ$-S	822*

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	NO	(2×2)–NO	188
	O_2	*(2×2)–O or (2×1)–O	124,180,181,182 183,184,827*
		Ir oxide	181
LaB_6(111)	[clean]	(1×1)	775,1328
	O_2	(1×1)	1328
Mg(0001)	[clean]	(1×1)	1289
	O_2	(1×1)R30°–MgO(111)	655
		$(\sqrt{7}\times\sqrt{7}/2)R19°$	655
		Disordered	1289
		(1×1)	797,1289
		MgO(111)	1671
Mo(111)	[clean]	(1×1)	1203
	H_2S	c(4×2)–H_2S	191
		MoS_2(0001)	191
	KCl	disordered	781
	N_2+NH_3	Disordered	1203
	N_2+NH_3	(433)facet	1203
		c(3×2)–N/Mo(433)	1203
	O_2	(211) facets	14,189
		(110) facets	189
		(4×2)–O	190
		(4×4)	898
		(1×3)	898
		(112)–(1×2) Facets	898
		(112)–(1×3) Facets	898
		MoO_2(100)	898
MoS_2(0001)	[clean]	*(1×1)	1706*
	Cs	Amorphous Layer	686,855
MoSe(0001)	[clean]	(1×1)	1035
	H_2O	Not Adsorbed	1035
	$HClO_4$	Not Adsorbed	1035
	I_2	Slightly Adsorbed	1035
	NaI_3	Slightly Adsorbed	1035
Na(0001)	[clean]	*(1×1)	1731*
Na_2O(111)	[clean]	*(1×1)	1755*
Nb(111)	O_2	(2×2)–O	192
		(1×1)–O	192
$NbSe_2$(0001)	[clean]	*(1×1)	1706*
Ni(111)	[clean]	*!(1×1)	1707*,1794!
	Ag	(6×6)	465,466
	Au	(6×6)	467,468,469,470
		(13×13)	467,468,469
	Bi	$(\sqrt{3}\times\sqrt{3})R30°$–Bi	864
		(7×7)–Bi	864
		$(\sqrt{7/4}\times\sqrt{7/4})R19°$–Bi	864
	Cl_2	$(\sqrt{3}\times\sqrt{3})R30°$–Cl	206
		$\begin{pmatrix}2 & 1\\ 4 & 7\end{pmatrix}$–Cl	206
	CO	!$(\sqrt{3}\times\sqrt{3})R30°$–CO	195,196,199,200,1314 1795!
		Hexagonal Overlayer	200

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		(2×2)-CO	3
		$(\sqrt{3}\times\sqrt{3})R30°$-O	5
		$(2\times\sqrt{3})$-CO	5
		$(\sqrt{39}\times\sqrt{39})$-C	5,27
		!(1×1)-C (graphite)	1907
		Disordered	198,1402
		$(\sqrt{7}\times\sqrt{7})R19.1°$	195,196
		$(\sqrt{7}/2\times\sqrt{7}/2)R19°$-CO	957,1402
		$c(4\times 2)$-CO	195,196,957,1402
		$c(2\times 2)$-CO	1314
		Complex Pattern	1402
	CO_2	(2×2)-CO_2	5
		$(\sqrt{3}\times\sqrt{3})R30°$-O	5
		$(2\times\sqrt{3})$-CO_2	5
		$(\sqrt{39}\times\sqrt{39})$-C	5,27
	GeH_4	$(\sqrt{3}\times 2\sqrt{3})R30°$	907
		$(\sqrt{3}\times\sqrt{3})R30°$-Ge	907
		(1×1)-Ge	907
	H_2	(1×1)-H	3
		(2×2)-(2)H	29,201,202,204 823*,1585,1666
		(2×1)	1667
		Disordered	203
	H_2S or S_2	*(2×2)-S	36,118,197,198 205*,294,577,990 992,1264,1493
		$(\sqrt{3}\times\sqrt{3})R30°$-S	36,118,577,1264
		(5×5)-S	36
		Adsorbed	36
		$(5\sqrt{3}\times 2)$	606,992
		$(8\sqrt{3}\times 2)$-S	607,608,609
		Complex	1493
	H_2Se	!(2×2)-Se	137,577,1708!
		(4×4)-Se	577
		$(\sqrt{3}\times\sqrt{3})R30°$-Se	137,577
	H_2O	$(\sqrt{3}\times\sqrt{3})R30°$	1308
	Mo	(5×5)	447,448
		(4×4)	447,448
		$\begin{pmatrix} 2 & 0 \\ 5 & 10 \end{pmatrix}$	447,448
		$\begin{pmatrix} 1 & 0 \\ 5 & 10 \end{pmatrix}$	447,448
	N_2	Not Adsorbed	131
	Na	Hexagonal	455,458,460
	NH_3	(2×2)-NH	778
		(6×2)-N	778
		$(\sqrt{7}\times\sqrt{7})R19°$	811,818
		Disordered	811
		$(\sqrt{7}/2\times\sqrt{7}/2)R19°$	1282
	$Ni(CO)_4$,CO	$(\sqrt{7}/2\times\sqrt{7}/2)R19°$-CO	1150
		$c(4\times 2)$-CO	1150

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	NO	c(4×2)–NO	193
		Hexagonal Overlayer	193
		(2×2)–O	193
		(6×2)–N	193
		(1×1)–NO	676
		c(4×2)–NO	676
		Complex	676
		(2×2)–O	676
		$\begin{pmatrix} 2 & 1 \\ 4 & 7 \end{pmatrix}$–Cl	206
	O_2	*(2×2)–O	2,3,4,116,193,194 195,196,197*,198 577,883,990,1282 1308,1346,1351 1652
		!($\sqrt{3}\times\sqrt{3}$)R30°–O	2,5,195,577,1346 1351,1652,1796!
		($\sqrt{3}\times\sqrt{21}$)–O	116
		NiO(111)	4,6,116,193,194
		NiO	1351
	O(a)+H_2O	No New Features	1308
	O(a)+NO	(2×2)	676
	Pb	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	471,472
		(7×7)	471,864
		(13×13)	471,472
		(3×3)	471,864,1060
		(4×4)–Pb	864,1060
		Hexagonal Rotated ± 3°	472
		($\sqrt{3}\times\sqrt{3}$)R30°–Pb	864,1060
	PF_3	(2×2)	833
Ni–17% Cu(111)	SiH_4	(2×2)	907
		($\sqrt{3}\times\sqrt{3}$)R30°–Si	907
Ni–25% Fe(111)		(2×2)–Si	907
NiI_2(0001)	Sn	(2×2)–Sn	1060
NiO(111)		($\sqrt{3}\times\sqrt{3}$)R30°–Sn	1060
$NiSi_2$(111)	Te	($2\sqrt{3}\times2\sqrt{3}$)R30°–Te	577
Os(0001)		($\sqrt{3}\times\sqrt{3}$)R30°–Te	577
	|clean|	(1×1)	868
	H_2	(2×2)–H	868
Pd(111)	$H_2S.H_2$	(3×3)–S	1121
	|clean|	!(1×1)	1908!
	Si	($\sqrt{3}\times\sqrt{3}$)R30°–Si	1185
	|clean|	*(1×1)	1770*
	CO	($\sqrt{3}\times\sqrt{3}$)R30°–CO	1169
		($2\sqrt{3}\times2\sqrt{3}$)R30°–CO	1169
		($3\sqrt{3}\times3\sqrt{3}$)R30°–CO	1169
	|clean|	*!(1×1)	1208,1509,1709! 1710*,1861*
	Au	!(1×1)–Au	1709!,1807

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Br_2	$(\sqrt{3}\times\sqrt{3})R30°$-Br	1103,1208,1327
		Ring pattern	1327
	C	Ring pattern	762
	Cl_2	$(\sqrt{3}\times\sqrt{3})R30°$-Cl	785
		(3×3)-Cl	785
	CO	*$(\sqrt{3}\times\sqrt{3})R30°$-CO	209,210,691,1042,1861*
		Hexagonal Overlayer	209
		c(4×2)-CO	210
		c(4×2)	691
		Disordered	1208
		(1×1)	1509
	CO_2	Not Adsorbed	691
	Fe	(1×1)	1546
	H_2	(1×1)-H	211,212
	H_2S	*$(\sqrt{3}\times\sqrt{3})R30°$-S	1710*
	NO	c(4×2)-NO	208
		(2×2)-NO	208
	O_2	(2×2)-O	207,691,1670
		$(\sqrt{3}\times\sqrt{3})R30°$-O	207
		(2×2)-PdO	207
		(1×1)	1509,1670
	O_2+CO	$(\sqrt{3}\times\sqrt{3})R30°$	691
		(2×1)	691
	PF_3	(2×2)	833
Pd-33% Ag(111)	{clean}	(1×1)	877
	CO	(1×1)	877
Pd-25% Cu(111)	{clean}	(1×1)	877
	CO	(1×1)	877
$Pd_2Si(0001)$	{clean}	(3×3)	1555
		(1×1)	1555
Pt(111)	{clean}	*!(1×1)	1226,1556,1614*,1711*,1712* 1799*,1874!
	Ag	Disorderd	1254
	Au	Disorderd	1254
	Br_2	(3×3)-Br	724
	Cu	(12×12)-Cu	1054
		(2×2)-Cu	1054
	C_2N_2	Disorderd	1002
	Cl_2+Br_2	c(2×4)-Cl,Br	610
		$(\sqrt{3}\times\sqrt{3})R30°$-Cl,Br	610
		(3×3)-Cl,Br	610
		$(\sqrt{7}\times\sqrt{7})R19.1°$	610
	CO	$(\sqrt{3}\times\sqrt{3})R30°$-CO	218,696,1205,1452
		*c(4×2)-2CO	28,107,120,218 219,696,981,1196 1205,1232,1237 1452,1711*
		Hexagonal Overlayer	218
		(2×2)-CO	120
		$(\sqrt{2/3}\times\sqrt{2/3})R15°$-CO	1232
		Ordered	1232
	CO+O_2	$(\sqrt{3}\times\sqrt{3})R30°$(Misfit)	909
	Cu	(1×1)-Cu	842

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		Cu(111) Multilayers	842
		Alloy Formation	842
	F	Streak Pattern	1694
	H_2	Not Adsorbed	120
		Adsorbed	220,221
		(1×1)–H	1110
	$H_2+C_2N_2$	Disorderd	1002
	H_2+O_2	$(\sqrt{3}\times\sqrt{3})R30°$	11
	H_2O	$(\sqrt{3}\times\sqrt{3})R30°-H_2O$	223,224,929
		$H_2O(111)$	224
		Not Adsorbed	580
	H_2S or S_2	(2×2)–S	225,226,227,247,933,1114,1248
		*$(\sqrt{3}\times\sqrt{3})R30°-S$	225,226,227,247,874,933,1114,1712*,1248
		Complex Structure	1114
		$\begin{pmatrix} 4 & -1 \\ -1 & 2 \end{pmatrix}-S$	225,226
		Hexagonal	227
	HBr	c(3×3)–3Br,HBr	806,1258
		(3×3)	806
	HCl	Disordered	806
	HI	$(\sqrt{3}\times\sqrt{3})R30°-I$	774
		$(\sqrt{7}\times\sqrt{7})R19.1°-I$	580,774
	I_2	$(\sqrt{7}\times\sqrt{7})R19.1°-I$	580,937,1106,1258 1391,1556
		$(3\sqrt{3}\times9\sqrt{3})R30°-I$	937
		$(\sqrt{3}\times\sqrt{3})R30°-I$	937,1258,1391
		(3×3)–I	937
	$I_2(a)+HBr$	HBr Not Adsorbed	1258
	I(a)+Cu	(3×3)–I,Cu	1556
		(10×10)–I,Cu	1556
	I(a)+Ag	(3×3)–Ag+I	937,1106,1391
		(5×5)–Ag+I	937
		(12×12)–Ag+I	1106
		(17×17)–Ag+I	937
		(18×18)–Ag+I	1106
		(18×18)+(10×10)–Ag+I	1106
		$(\sqrt{7}\times\sqrt{7})+(3\times3)$	1391
		$(\sqrt{3}\times\sqrt{3})R30°-Ag,I$	1391
	K	$(\sqrt{3}\times\sqrt{3})R30°-K$	1071,1238,1337
		$\begin{pmatrix} 1.66 & 0 \\ 0 & 1.66 \end{pmatrix}-K$	1337
		"Ring" Pattern	1337
	K+CO	Disorderd	1255
	$K+O_2$	(4×4)–K,O	1238,1337
		(8×2)	1337
		(10×2)	1337
		K_2O	1337
	N	Disordered	228
	NH_3	Disordered	599
		Adsorbed	626
		Not Adsorbed	580

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	NO	Disordered	222
		(2×2)–NO	690,1030,1096
	NO_2	Disorderd	1227
		(2×2)–O,NO,(NO_2)	1227
	O_2	(2×2)–O	10,11,213,214,215 216,217,581,952 1221,1237,1248 1301
		(2×2)–O,(O_2)	1221
		($\sqrt{3}$×$\sqrt{3}$)R30°–O	214,215,217,708
		(1×1)–O	708,1171
		Not Adsorbed	120
		(4$\sqrt{3}$×4$\sqrt{3}$)R30°–O	214,215
		PtO_2(0001)	214,215
		(3×15)–O	217
		disordered	581
		(3/2×3/2)R15°–O_2	1221
	SO_2	Disorderd	1179
	S+O_2	(2×2)–O	1040
	O_2	Not Adsorbed	1248
	Xe	($\sqrt{3}$×$\sqrt{3}$)R30°–Xe	846
		Hexagonal	846
PtNi(111)	[clean]	*(1×1)	1909
Pt–22% Ni(111)	[clean]	(1×1)	1162
Pt–50% Ni(111)	[clean]	(1×1)	1162
Pt_3Ti(111)	[clean]	(2×2)	935
Re(0001)	Ba	(2×2)	565,566
		Hexagonal	565,566
	CO	Not Adsorbed	24
		(2×2)–CO	23
		Disordered	230,1132
		($\sqrt{3}$×4)	1176
		(2×$\sqrt{3}$)	230
	H_2	Not Adsorbed	24
		Disordered	664
	H_2O	($\sqrt{3}$×$\sqrt{3}$)R30°–H_2O	1003
		(2×2)–H_2O	1003
	N_2	Not Adsorbed	24
	O_2	(2×2)–O	23,24,229,723
		Ordered	1515
		(2×1)–O	972,1654
Re(0001) on Pt(111)	CO	($\sqrt{3}$×4)rect	843
		(2×2)	843
	O_2	(2×1)–O	843
Rh(111)	[clean]	*(1×1)	1648,1713*,1800*
	C	(2$\sqrt{3}$×2$\sqrt{3}$)R30°–C	1012
	C_2N_2	Adsorbed	926
	Cl_2	($\sqrt{3}$×$\sqrt{3}$)R30°–Cl	654
		(4×4)–Cl	654
	CO	*($\sqrt{3}$×$\sqrt{3}$)R30°–CO	231,652*,727,931
		*(2×2)–3CO	12,231,727,931 1122*
		($\sqrt{3}$×7)rect	1844

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	CO+Na	c(4×2)–CO+Na	1844
	CO+NO	Disordered	1876
	CO_2	$(\sqrt{3}\times\sqrt{3})R30°$–CO	231
		(2×2)–CO	231
	H_2	Adsorbed	231
	H_2+CO	(2×2)	829
		$(\sqrt{3}\times\sqrt{3})R30°$	829
		(2×2)	829
	H_2O	$(\sqrt{3}\times\sqrt{3})R30°$–$H_2O$	583
	H_2S or S_2	c(2×4)–S	875
		*$(\sqrt{3}\times\sqrt{3})R30°$–S	1768*
	NO	c(4×2)–NO	231
		(2×2)–NO	231
	O_2	(2×2)–O	12,231
		Disordered	570,583
		(2×2)	570
		(2×1)–O	1692
		(8×8)–Rh_2O_3(0001)	1692
Ru(0001)	[clean]	*(1×1)	914,1127*,1233,1380
	C_2N_2	c(2×2)–CN	1217
		(3×3)–CN	1217
		c(4×8)–CN	1217
		(1×2)	1217
		(1×3)	1217
		(1×1)	1217
		Graphite	1217
	CO	*$(\sqrt{3}\times\sqrt{3})R30°$–CO	12,233,248,716 825,914,1127* 1357
		(2×2)–CO	12,248
		$(2\sqrt{3}\times2\sqrt{3})R30°$–CO	716,825
		$(5\sqrt{3}\times5\sqrt{3})R30°$–CO	825
	CO+O_2	(2×2)	768
	CO_2	$(\sqrt{3}\times\sqrt{3})R30°$–$CO_2$	12
		(2×2)–CO_2	12
	Cu	Disordered	1679
	H_2	(1×1)–H	234,870
	H_2O	$(\sqrt{3}\times\sqrt{3})R30°$ + "halo"	1233,1380
		$(\sqrt{3}\times\sqrt{3})R30°$	835,1380
		$(\sqrt{3}\times\sqrt{3})R30°$–$H_2O$	1082
		"Hexagon"	1233,1380
		(2×2)–O_2	1233
		Complex	1233
	H_2S	(2×2)	740
		$(\sqrt{3}\times\sqrt{3})R30°$	740
		c(4×2)	740
	Na	(3/2×3/2)–Na	1129,1406
		Ring Pattern	1129
		(2×2)–Na	1082,1129
		$(\sqrt{3}\times\sqrt{3})R30°$–Na	1082,1129,1406
		Hexagonal Overlayer	1406
	Na+CO	$(2\sqrt{3}\times2\sqrt{3})R30°$	976
	Na+H_2O	$(2\sqrt{3}\times2\sqrt{3})R30°$	1082
		Complex	1082

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	N_2	Adsorbed	234
		$(\sqrt{3}\times\sqrt{3})R30°-N_2$	1455
	N_2O	(2×2)	832
	NH_3	$(2\times2)-NH_3$	234,235,1045
		$(\sqrt{3}\times\sqrt{3})R30°-NH_3$	235
		$(2\sqrt{3}\times2\sqrt{3})R30°-NH_3$	1045
	NO	(2×2)–NO	598
		$(2\sqrt{3}\times2\sqrt{3})R30°-NH_3$	1045
		(2×1)–NO	963
	O_2	(2×2)–O	12,232,248,832
			1233
		(2×1)–O	963,1233
		(1×2)–O	619,631
	O(a)+NO	Disordered	963
Sb(0001)	Fe	(1×1)	567
	Th	$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	510,511
Sc(0001)	[clean]	*(1×1)	1333*
Si(111)	[clean]	*!(2×1)	847,856,947,954
			956,1019,1028
			1086,1087,1361
			1374,1412*,1427,1428
			1457,1477,1528,1533
			1542,1543,1563
			1646*,1714!
		(7×7)	851,857,921,934,954
			996,1019,1021,1022
			1056,1073
			1158,1170,1206,1207
			1210,1342,1457
			1475,1477,1483,1486
			1499,1507,1517
			1525,1529,1533
			1536,1537,1543
			1685
		(1×1)	568,954,1366,1427
			1457,1492,1543
			1544
		$(\sqrt{19}\times\sqrt{19})$	1653
	Laser-annealed	*(1×1)	1170,1492,1517,1716*
		(1×1)+Steps	1446
	Ag	(6×1)–Ag	795,807,948,1158
			1342,1696
		$(\sqrt{7}\times\sqrt{7})R19.1°$–Ag	1696
		*!$(\sqrt{3}\times\sqrt{3})R30°$–Ag	807,923,1037,1073
			1108,1158,1206
			1322,1342*,1536
			1650,1696,1910!,1911!
		*(3×1)–Ag	807,948,1037,1158
			1342*,1536,1696
		$\sqrt{3}(3\times1)$	1536
		(1×1)–Ag	1022,1206
		!Ag Island	1911!

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Ag(a)+H	$(\sqrt{3}\times\sqrt{3})R30°$	1536
	Al	$(\sqrt{7}\times\sqrt{7})R19.1°$–Al	816
		(1×1)	1563
		$(\sqrt{3}\times\sqrt{3})R30°$	816,1563
	Au	(5×1)–Au	792,1091,1628 1669
		$(\sqrt{3}\times\sqrt{3})R30°$–Au	792,1091,1215 1322,1499,1628 1669
		(6×6)–Au	792,1091,1215
		(1×1)–Au	956,1091
	Bi	$(\sqrt{3}\times\sqrt{3})R30°$–Bi	736
		Bi(0001)–(1×1)	736
	Br	!Not Specified	1858!,1859!
	Cl	(7×7)	1088
		$(\sqrt{19}\times\sqrt{19})$–Cl	1088,1385
	Cl_2	Disordered	138
		!(7×7)–Cl	138,236,1715!
		!(1×1)–Cl	138,236,1715!
	Co	(1×1)	851
		(1×1)–$CoSi_2$	851,1414
		$(\sqrt{7}\times\sqrt{7})$–2d Silicide	851
		(2×2) or (2×1)–2d Silicide	851
	Cr	(1×1)	1500
		$(\sqrt{3}\times\sqrt{3})R30°$	1500
		(7×7)	1500
	Cu	(1×1)–Cu	841
		Cu(111) or Cu-Si(111) [Multi Layers]	841
		5×5–Cu	841,857,858
		(4×1)	856
		(4×2) [Multi Layer]	856
		Cu(111)–$\sqrt{3}\times\sqrt{3}$ [Multi Layer]	856
		Cu(111)–(1×1) [Multi Layer]	856
	Cu(a)+O_2	"5×5"	856
	D_2	(7×7)	1369
	Ga	$(\sqrt{3}\times\sqrt{3})R30°$–Ga	1028
		(1×1)–Ga	1028
		(7×7)–Ge	1029,1537
		(1×1)–Ge	1029,1486,1544
		(5×5)	1475,1483,1486
		(5×5)–Ge	1029
		(5×5)–SiGe(111)	934,1010
		Ordered	1507
		$(\sqrt{3}\times\sqrt{3})R30°$	1544
	H_2	(1×1)–H	237,1216,1477
		(7×7)–H	237,904,1610
		(2×1)	1477
	H_2O	(1×1)	1477
		Adsorbed	903
	I	*(7×7)–I	1088*
	I_2	(1×1)–I	133
		!(7×7)–I	1857!

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	In	$(\sqrt{3}\times\sqrt{3})$R30°–In	1028
		(2×2)–In	1028
		Complicated	1028
	Kr	(7×7)	1125
	N_2	(8×8)–N	34,586,1229
		Doublet	586
		Diffuse	586
		Si(1×1)	1229
		"Quadruplet"	1229
	N	(1×1)	798
	NH_3	(8×8)–N	238
		(7×7)+"quadruplet"	1479
		(7×7)+(8×8)	1479
	Ni	!(1×1)–$NiSi_2$	838,1434,1659,1860!
		(1×1)–Ni	850,1366,1434
		Disordered	964
		(1×1)–Ni w.streaks	964
		$(\sqrt{3}\times\sqrt{3})$R30°	964,969
		$(\sqrt{19}\times\sqrt{19})$R±23.5°–Ni	964,1366
		Si(111)–(7×7)	964
	NO	Disorderd	1021
		(8×8)–N	1021
		Complex	1021
	O_2	Disordered	17,20,21
		(1×1)	847
	P	$(6\sqrt{3}\times6\sqrt{3})$–P	132,133
		(1×1)–P	132
		$(2\sqrt{3}\times2\sqrt{3})$–P	132
		(4×4)–P	133
	Pd	Disordered	964,1207
		(5×1)	964
		$(\sqrt{3}\times\sqrt{3})$R30°-Pd	964,1456,1484 1487,1496
		(3×1)–Pd	1456
		(1×1)+Streaks	964,1456
		$(2\sqrt{3}\times2\sqrt{3})$R30°–Pd	964,1456
		Pd_2Si (Epitaxial)	1134
	PH_3	(7×7)–P	239
		(1×1)–P	239
		$(6\sqrt{3}\times6\sqrt{3})$–P	239
		$(2\sqrt{3}\times2\sqrt{3})$–P	239
	Si	(1×1)	1517
	Si+laser	(1×1)	1392
	Sb	(1×1)–Sb	1019
	Sn	(1×1)–Sn	996
		$(\sqrt{3}\times\sqrt{3})$R30°–Sn	996
		$(2\sqrt{3}\times2\sqrt{3})$R30°–Sn	996
		$(\sqrt{133}\times4\sqrt{3})$–Sn	996
		$(3\sqrt{7}\times3\sqrt{7})$R(30±10.9)°–Sn	996
		$(2\sqrt{91}\times2\sqrt{91})$R(30±3.0)°–Sn	996
	Te	!(7×7)–Te	1088,1857!
		(1×1)–Te	1617
	Yb	(2×1)–Yb	844,1525
		(3×1)–Yb	844,1525

TABLE III. Surface Structures on Substrates with Three-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		(2×1)+(7×7)	844
		(5×1)–Yb	1525
	Xe	(7×7)	1125
Ti(0001)	[clean]	*(1×1)	1007,1717*
	Cd	*(1×1)	562*,563,564
	CO	(1×1)–CO	18,240
		(2×2)–CO	240
		$(\sqrt{3}\times\sqrt{3})$R30°–N	241,242
	Cu	Extra Spots	561
	N_2	*(1×1)–N	241,242*
		$(\sqrt{3}\times\sqrt{3})$R30°–N	241,242
	O_2	(1×1)–O	18
TiC(111)	[clean]	(1×1)	1631
Th(111)	CO	Disordered	243
		ThO_2(111)	243
	O_2	Disordered	243
		ThO_2(111)	243
UO_2(111)	O_2	(3×3)–O	13
		$(2\sqrt{3}\times2\sqrt{3})$R30°–O	13
W(111)	Cl_2	Facet Surface	796
	CO	Disordered	746
		{211} facets	746
	O_2	Disordered	244,746
		{211} facets	15,746
		(4×4)–O	746
Y(0001)	[clean]	(1×1)	1120
Xe(111)	[clean]	*(1×1)	1912*
Zn(0001)	[clean]	*(1×1)	1267,1870*
	Cu	(1×1)	449,450
	O_2	(1×1)–O	122
		ZnO(0001)	245
	SO_2	No LEED Pattern	1569
		Oxide	1569
Zn(000$\overline{1}$)	O_2	$(\sqrt{3}\times\sqrt{3})$R30°–O	122
ZnO(0001)	[clean]	*(1×1)	1104,1239,1773*
	H_2O	Disordered	1104
ZnO(000$\overline{1}$)	[clean]	(1×1)	1104
	H_2O	Disordered	1104
	K	$(2\sqrt{3}\times2\sqrt{3})$R30°–K	1629
	Xe	Disordered	1026
ZnSe(111)	[clean]	(2×2)	1393
		(1×1)+{110}facet+(2×2)	1393
ZnSe($\overline{111}$)	[clean]	(1×1)	1393
		(1×1)+{331}f+{110}f,{110}f	1393
ZnTe(111)	[clean]	(2×2)	1393
		(1×1)	1393
ZnTe($\overline{111}$)	[clean]	(1×1)+{331}f+{110}f	1393
Zr(0001)	[clean]	*(1×1)	1473,1642*
	O_2	*(2×2)–O	1718*

†Organic overlayer structures are not included. See Table VII for these structures.

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry†

Substrate	Adsorbate	Surface Structure	Reference
Ag(100)	[clean]	*(1×1)	1272,1562,1897*,1898*,1899*
	Au	(1×1)	1806
	Cl_2	!c(2×2)–Cl	572,605,732,962
			1719!
	Cl_2+K	c(2×2)–K/Cl	673
	Cu	Epitaxial	1167
		Cu(100)	1476
		(1×1)	1820
	Fe	(1×1)	1272
	H_2O	Disordered	1034
	H_2S	(2×2)–S	627
		$\begin{pmatrix} 4 & -1 \\ 1 & 4 \end{pmatrix}$–S	627
		$\begin{pmatrix} 4 & 4 \\ -4 & 4 \end{pmatrix}$–S	627
		Partially Disordered	1117
	I_2	c(2×2)–I	1145
	K+O_2	$\begin{pmatrix} 1 & 1 \\ -5 & 4 \end{pmatrix}$	658
		Hexagonal Overlayer	658
	Ni	(1×1)	1820
	O_2	Disordered	146
	O(ad.)+H_2O	c(2×2)–OH	1034
	Pd	Epitaxial	1167
		(1×1)	1463
	Se	*c(2×2)–Se	250*
Al(100)	[clean]	*!(1×1)	1077!,1354,1532
			1720*,1721*
	Ag	(5×1)–Ag	1363
		(1×1) [Multilayer]	1363
	Au	Disordered	1363
	CO	Not Adsorbed	1273
		Disordered	1368
	Cu	Disordered	1363
	Fe	Poor Epitaxy	452
	H_2	(1×1)	1693
	Na	*c(2×2)	499*,500,501,1720*
		Hexagonal Overlayer	500
	O_2	Disordered	42,43,44,709
	Pb	$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	503
		c(2×2)–Pb	704
		$\begin{pmatrix} 2 & 0 \\ 1 & n \end{pmatrix}$–Pb	704
		$2<n<3$	
	Sm	(1×1) Disorder	1532
		Complicated	1532

†Organic overlayer structures are not included. See Table VII for these structures.

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Sn	$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	503
		c(2×6)–Sn	704
		$\begin{pmatrix} 2 & 0 \\ 1 & n \end{pmatrix}$–Sn, $2<n<3$	704
Au(100)	[clean]	(1×5)	1153
		c(26×68)	1153
		(5×20)	1170,1361
		$\begin{pmatrix} X & 0 \\ Z & Y \end{pmatrix}$ X=24±3,Y=43 or 48,−5≤Z≤0	967
	Laser-annealed	*(1×1)	1170,1293,1361 1722*
	Ag	(1×1)	473,474,494,1838
	Bi	$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	498
	Br_2	(1×1)–Br	793
		c(2×2)–Br	793
		$(\sqrt{2}\times 4\sqrt{2})R45°$	793
		c(4×2)	793
	CO	Disordered	252
	Cu	(1×1)	473
	Fe	(1×1)	1828–1830
	H_2S	(2×2)–S	251
		c(2×2)–S	251
		(6×6)–S	251
		c(4×4)–S	251
	Na	Hexagonal	492
		Ordered	492
	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	441–444
		$\begin{pmatrix} 1 & 1 \\ -3 & 4 \end{pmatrix}$	441–444
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	441–444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	441–444
		(1×1)	683
	Pd	(1×1)	473,1833
		c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
	Pt	(1×1)	438,439,440
	Xe	Disordered	252

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
$BaTiO_3(100)$	[clean]	(2×2)	853,1490
		(3×3)	1490
		(1×1)	853,1490
	O_2	Disordered	853
C(100),diamond	H_2S	Not Adsorbed	164
	N_2	Not Adsorbed	164
	NH_3	Not Adsorbed	164
	O_2	Disordered	16
		Not Adsorbed	164
CaO(100)	[clean]	*(1×1)	755*,1641*
Ce(100)	[clean]	$\begin{pmatrix} \frac{3}{5} & \pm\frac{1}{5} \\ \frac{1}{5} & \pm\frac{2}{5} \end{pmatrix}$	845
Co(100)	[clean]	*(1×1)	1539,1776*
	C	(2×2)–C	1539
	CO	c(2×2)–CO	253,1553
		(2×2)–C	253
	H_2S or S	(2×2)–S	1539
		*c(2×2)–S	1539,1548,1698*
	H_2S+C	(2×2)–S,C	1539
	O_2	(2×2)–O	254
		*c(2×2)–O	254,1777*
	S	*c(2×2)–S	1698*
CoO(100)	[clean]	*(1×1)	1778*
Cr(100)	[clean]	(1×1)	1126,1330,1606
	C,O,N	c(2×2)	1126
	Br_2	c(2×2)–Br	1051
		c(2×4)–Br	1051
		Pseudohexagonal $CrBr_2$	1051
	Cl_2	c(2×2)–Cl	1330
		(2×5)–Cl	1330
		c(2×4)–Cl	1330
	H_2S	c(2×2)–S	1245
	N	(1×1)–N	1330
		$(\sqrt{2}R45°\times\sqrt{5}R27°)$–N	1330
		c(2×2)–N	1330
	N_2	c(2×2)–N	1245
		$c(\sqrt{2}\times3\sqrt{2})R\pm45°$–N	1245
		(1×1)–N	1245
	O_2	c(2×2)–O	255,634,1245
		$Cr_2O_3(310)$	256
		(1×1)–O	1245
		c(2×4)–O	1245
	Br_2	c(2×2)–Br	1051
		c(2×4)–Br	1051
		CrB_2	1051
Cu(100)	[clean]	*(1×1)	585,1101,1419 1723*
	Ag	$\begin{pmatrix} 2 & 0 \\ -1 & 5 \end{pmatrix}$	473,477

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Au	$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	473,478
		$\begin{pmatrix}2 & 0\\ -1 & 7\end{pmatrix}$	473,478
	Bi	(2×2)	483,486
		$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	483,486
		$\begin{pmatrix}1 & 1\\ -4 & 5\end{pmatrix}$	483,486
		$\begin{pmatrix}5 & 4\\ -4 & 5\end{pmatrix}$	483,486
		(1×1)	703
		c(2×2)	703
	Cl_2	*!c(2×2)–Cl	1081,1102,1461 1545,1724*,1869!
	Co	(1×1)–Co	983,1105,1810 1811
	Co (Multilayer)+CO	c(2×2)–CO	983
	CO	*c(2×2)–CO	125,126,265,1005 1353,1407,1605 1663,1780*
		$(7\sqrt{2}\times\sqrt{2})R45°$–CO	1407
		$(\sqrt{2}\times\sqrt{2})R45°$	1626
		Hexagonal Overlayer	126,127,265
		(2×2)–C	26,125
	Cs	Disordered	865
	Cs	Hexagonal Overlayer	865
		Quasi-Hexagonal	865
	Fe	(1×1)	452,1808,1809
	H_2S	Adsorbed	35
		!(2×2)–S	35,260,262,1211 1725!
		(2×1)–S	128
		Partially Disordered	1117
	I_2	!(2×2)–I	1779!
	K	$\begin{pmatrix}2 & 3\\ 0 & 5\end{pmatrix}$	1405
		$\begin{pmatrix}2 & 2\\ 0 & 3\end{pmatrix}$	1405
		Incommensurate	1405
	Mn	c(2×2)–Mn	1319
	N_2	(1×1)–N	49
		c(2×2)–N	47,132,258,261 266
	Nb	Incommensurate	667
	Ni	(1×1)	1812

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	O_2	(1×1)-O	9,45
		(2×1)-O	9,45,46
		(2×4)R45°-O	7,47,246,261
		(2×3)-O	119
		c(4×4)-O	119
		*!c(2×2)-O	171,246,257,258 259,260,263,264 1417,1726!,1727! 1781*
		(2×2)	171
		$(2\times2\sqrt{2})$R45°	259,262,263,264
		Hexagonal	259
		(410) facets	259
		$(\sqrt{2}\times\sqrt{2})$R45°-O	641,1095,1285 1598,1633
		*$(\sqrt{2}\times2\sqrt{2})$R45°-O	1095,1781*
		$(2\sqrt{2}\times2\sqrt{2})$R45°-O	1633
		$(\sqrt{2}\times0.46\text{nm})$R45°-O [Coincidence]	1691
	Pb	$\begin{pmatrix} 2 & 2 \\ -2 & 2 \end{pmatrix}$	481–485
		$\begin{pmatrix} 1 & 1 \\ -2 & 3 \end{pmatrix}$	481–485
		*c$(5\sqrt{2}\times\sqrt{2})$R45°-Pb	703,1295*
		*c(2×2)-Pb	1295*
		$(2\sqrt{2}\times2\sqrt{2})$R45°-Pb	1295
	Sn(θ>1)+Pb	Disordered	1041
	Pd	c(2×1)-Pd	726
		(1×1)-Pd	726,1649
		c(2×2)-Cu_3Pd	1649
	Sn	(2×2)	480
	Te	*!(2×2)-Te	267*,1119,1728!
	Tl	$\begin{pmatrix} 2 & 2 \\ 2 & -2 \end{pmatrix}$	1167,1564
		$\begin{pmatrix} 4 & 0 \\ 2 & 7 \end{pmatrix}$-Tl	1167,1336,1564
		$\begin{pmatrix} 4 & 0 \\ 2 & 6 \end{pmatrix}$-Tl	1336,1564
		$\begin{pmatrix} 6 & 6 \\ 2 & -2 \end{pmatrix}$	1564
		c(4×4)-Tl	1336
	Xe	Hexagonal Overlayer	159
		Disordered	741
Cu-3% Al(100)	O_2	c(2×2)-O	1632
		Disordered	1632
Cu-5.7% Al(100)	[clean]	(1×1)	813
Cu-12.5% Al(100)	[clean]	(1×1)	813
Cu_3Au(100)	[clean]	c(2×2)	916

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Cu/Au(100)	[clean]	c(2×2)	737
Cu/Pd(100)	[clean]	Streak	737
		c(2×2)	737
CuSn(100)	[clean]	c(2×2)	1481
		$(3\sqrt{2}\times\sqrt{2})R45°$	1481
		c(3×2)+(2×2)	1481
Cu–25% Zn(100)	[clean]	(1×1)	1152
	O_2	Disordered	1152
EuO(100)	[clean]	(1×1)	1502
Fe(100)	[clean]	*(1×1)	989,1078,1729*
	Br_2	c(2×2)	752
		$(2\sin\alpha'\times 2\sin\alpha')R\alpha'$	752
		$\alpha' = 26.57°, 37.49°, 40.5°$	
		$\begin{pmatrix} 1 & \frac{1}{\tan\alpha} \\ -1 & \frac{1}{\tan\alpha} \end{pmatrix}$	752
		$\alpha = 53.13°, 53.47°, 56.31°$	
		$(\sqrt{41}/5\times\sqrt{41}/5)R38.7°$	752
		c(2×4)	752
	CBr_4	c(2×2)	757
		$(2\sin\alpha'\times 2\sin\alpha')R\alpha'$	757
	CCl_4	$(2\sin\alpha'\times 2\sin\alpha')R\alpha'$	753
		$(\sqrt{13}\times\sqrt{13}))R\tan^{-1}(2/3)$	753
		(6×6)–Cl	753
		$\begin{pmatrix} 1 & \frac{1}{\tan\alpha} \\ -1 & \frac{1}{\tan\alpha} \end{pmatrix}$	753
		c(2×2)	753
	CO	*c(2×2)–CO	275*,1596
		*c(2×2)–C,O–Disordered	783,893,1601*
		Disordered	783
	Fe_3O_4	(1×1)–like	1189
	H_2	Adsorbed	177
	H_2O	c(2×2)	278
	H_2S or S	*c(2×2)–S	276,277*,1552,1630
		Complex	1552
		c(6×2)	1552
	I_2	c(2×2)–I	751
		(2sin40.5×2sin40.5)R40.5°–I	751
		$(\sqrt{85}\times\sqrt{85})R40.6°$–I	751
	K	Disordered	665
		(2×2)–K	784
		Hexagonal Close Pack	784
	N	c(2×2)–N	893
	NH_3	Disordered	176
		*c(2×2)–N	176,1224*
	O_2	c(2×2)–O	60,269,270,271 274,635,893,1596
		*(1×1)–O	144,268*,271,272 1596

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		FeO(100)	60,269,270,272 273,635
		FeO(111)	270,635
		FeO(110)	272
		Disordered	273,276
	Se	c(2×2)–Se	1078
	Si	c(2×2)–Si	985,986
	Te	(2×2)–Te	1204
		c(2×2)–Te	1204
Fe/Cr(100)	O_2	c(2×2)–O	279,636
		c(4×4)–O	279
		Oxide	280
FeTi(100)	[clean]	(1×1)	1241
	S	c(2×2)–S	1241
Ge(100)	[clean]	!(2×1)	1094,1213,1522,1636 1645,1783!
		(2×2)	1449
		(4×2)	804
	Ag	(1×1)–Ag	1522
	Bi	(1×1)–Bi	1449
	I_2	(3×3)–I	19
	O_2	Disordered	17,18
		(1×1)	1094
Ir(100)	[clean]	*(1×1)	866,1199*,1293 1361,1381
		*(5×1)	866,1156*,1361 1381,1785*
	Ba	(2×1)–Ba	1399
	CO	c(2×2)–CO	48
		(2×2)–CO	48
		(1×1)–CO	282
	CO_2	c(2×2)–CO_2	48
		(2×2)–CO_2	48
		(7×20)–CO_2	48
	Cs	c(4×2)–Cs w.Streak	1395
		Close Packed Layer	1395
		Compressed Layer	1395
		(5×5)–Cs	1395
	H_2	Adsorbed	281
	K	c($2\sqrt{2}\times4\sqrt{2}$)R45°	866
		$\begin{pmatrix} 2 & 1 \\ -1 & 2 \end{pmatrix}$	866
		c(4×2)	866
		(3×2)	866
		c(2×2)	866
		$\begin{pmatrix} \frac{5}{2} & 0 \\ \frac{-5}{4} & \frac{5}{3} \end{pmatrix}$	866
		$\begin{pmatrix} 2 & 0 \\ -1 & \frac{5}{3} \end{pmatrix}$	866

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{bmatrix} \frac{10}{7} & 0 \\ \frac{-5}{7} & \frac{5}{3} \end{bmatrix}$	866
	Kr	(3×5)–Kr	283
		Kr(111)	283
	NO	(1×1)–NO	188
	O_2	(2×1)–O	48,281
		(5×1)–O	48
	O_2	(1×1)–O	797
KBr(100)	[clean]	(1×1)	1592
KCl(100)	[clean]	(1×1)	1592
LaB_6(001)	[clean]	(1×1)	738,1625
	O_2	(1×1)	770
MgO(100)	[clean]	*(1×1)	755,908,918,1067*,1139,1284 1574*
	Ag	(1×1)	1559
Mo(100)	[clean]	*(1×1)	761*,1379
	Ag	Ag(100)	513,514
		Ag(110)	513,514
	CO	Disordered	62,693
		(1×1)–CO	62,64,285,286 1379
		c(2×2)–CO	64,285,286
		(4×1)–CO	64
	Cs	$(\sqrt{2}\times\sqrt{2})R45°$	932
		(2×2)	932
		c(2×2)	932
		Rectangular Centered Mesh	932
		Quasi Hexagonal	932
		Hexagonal Overlayer	932
	Cs(a)+O_2	c(2×2)+(4×1)	932
		(4×1)	932
		Disordered	932
	O(a)+Cs	c(2×2)–Cs+O	932
		(110) Microfacets	932
		Disordered	932
	Ga	(1×1)–Ga	789
	H_2	c(4×2)–H	77
		(3×2)–H	780
		$(\sqrt{2}\times\sqrt{2})$–H	780,814
		(1×1)–H	77
	H_2S, S, or S_2	(1×1)–S	130,1149
		(1×1)–S Diffuse	1174
		$(\sqrt{5}\times\sqrt{5})$–S	130,288
		*c(2×2)–S	130,578,917,998, 1039,1149,1174,1913*
		MoS_2(100)	288
		(2×1)–S	578,612,917,998,1039,1149,1174
		$(\sqrt{5}\times\sqrt{5})R26.6°$	578,613

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		c(4×4)–S	578,613,998
		c(4×2)–S	578,917,998,1039,1149 1174
		$\begin{pmatrix} 1 & 1 \\ 2 & -1 \end{pmatrix}$–S	578,917,998,1039,1174,1149
	H_2S+O_2	$(\sqrt{5}\times\sqrt{5})R26.6°$–S,O	917
	N_2	(1×1)–N	62
		*c(2×2)–N	287*
	O_2	Disordered	61,62
		c(2×2)–O	61,62,63,64,284 660,898
		$(\sqrt{5}\times\sqrt{5})R26°$–O	61,62,189,190,284 660,898,1155,1379
		(2×2)–O	61,189,190,660 1379
		c(4×4)–O	62,189,284,660 898
		*(2×1)–O	189*,190,660,748 898
		(5×5)–O	748
		(4×1)	898
		(6×1)–O	748
		(6×2)–O	284,660,7484
		(3×1)–O	284,748
		(1×1)–O	284,660,898,1155
		c(4×4)+(2×1)–O	748
		(2×1)+c(2×2)	748
		Microfacet	660
		streak(1×1)–O	660
		diffuse(1×1)–O	660
		Facet	748
		(110),(112) Facets	898
		$MoO_2(110)$	898
	O(a)+CO	(2×1)–O	817
	$O(a)+CO_2$	(2×1)–O	817
	Si	*(1×1)–Si	1730*
	Sn	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	516
		(1×2)	516
		(1×1)–Sn	789
		c(2×2)–Sn	789
NaCl(100)	Ag	Ag(111)	1678
	Xe	Hexagonal Overlayer	289
$Na_{0.47}WO_3(100)$	{clean}	(3×1)	808
$Na_{0.72}WO_3(100)$	{clean}	(2×1)	808
		c(2×2)	808
$Na_{0.79}WO_3(100)$	{clean}	(2×1)	1485
Nb(100)	N_2	(5×1)–N	290
	O_2	c(2×2)–O	192,290
		(1×1)–O	192,290
		(3×10)–NbO_2	290

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ni(100)	[clean]	*!(1×1)	973,1092,1231
			1458,1561,1565,1739!,1864*
	Ba	Disordered	454
	C	*(2×2)–C	640,745*,1231,1673
	C(a)+O_2	c(2×2)–O	1177
	Cl_2	(2×2)–Cl	662
		c(2×2)–Cl	662
	Co	(1×1)	1803
	CO	*!c(2×2)–CO	54,55,68,129,198
			300,301,302,747*
			782,950,981,993
			1202,1604*,1605
			1789*,1790*,1791!,1795!
		c(2×2)	1281
		(2×2)–CO	69
		c($\sqrt{2}$×3$\sqrt{2}$)R45°–CO	1202
		Hexagonal Overlayer	129,301,302
		(2×2)–C	198
		Disordered	1291
	CO+H_2	c(3×3)	301
	CO_2	(2×2)–O+c(2×2)–CO	76
	Cr	(1×1)	463,464
	Cs	(2×2)	454
		Hexagonal	463,464
	Cu	*(1×1)–Cu	1113,1458*,1804
	e beam	(2×2)	1401
	Fe	c(2×2)–Fe	973
		(2×2) (Multilayer)	973
		c(2×2) (Multilayer)	973
		Fe(110) (Multilayer)	452,973
	H_2	Disordered	198,203,211
		c(2×2)–H	301
		(1×1)–H	1092,1202,1658
		(1×1)–H streaked	663
	H_2+CO	c(2×2)–CO,H	1202
		c($\sqrt{2}$×2$\sqrt{2}$)R45°–CO,H	1202
	H_2S, S, or S_2	*(2×2)–S	36,118,197,198
			621,622,623
			637,979,1329,1508
			1732*
		*!c(2×2)–S	36,118,197!,198
			293,294,303,304
			340,621–623
			681,979,1121,1329
			1482,1725!,1734!,1735!,1736!,1792*
			1793!,1852!
		(2×1)–S	198
		c(2×2)–H_2S	304
		Ni_3S_2 Island	681
	H_2S,H_2	c(2×2)–S	1121
	H_2S+Na	*c(2×2)Na+c(2×2)S	1887*
		*(2×2)Na+c(2×2)S	1887*
		*(2×2)Na+(2×2)S	1887*

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	H_2Se	*(2×2)–Se	197,198,1732*,1866!
		*c(2×2)–Se	142,197,198,293
			294,305,340*,1733!
		(2×1)–Se	198
		c(4×2)–Se	305
	H_3P	Disordered	662
	HCl	c(2×2)–HCl	1644
		c(2×2)–Cl	1644
	I_2	c(2×2)–I	1036,1148
		NiI_2	1148
		$\begin{pmatrix} 1-\frac{1}{\tan\theta} & -1-\frac{1}{\tan\theta} \\ \frac{2}{\tan\theta} & \frac{2}{\tan\theta} \end{pmatrix}, \theta\sim 61^\circ$	1148
		$\begin{pmatrix} 5 & -3 \\ 3 & -5 \end{pmatrix}$	1148
		$\begin{pmatrix} 7 & -5 \\ 3 & \frac{3}{5} \end{pmatrix}$	1148
		(2×4)–I_2	1148
	K	(4×2)	454
		Hexagonal	457,461,462
	N_2	Not Adsorbed	80,81
		(2×2)–N	772,1578
		c(2×2)–N_2	984,987
	N_2H_2	(2×2)–N	690
	Na	*c(2×2)–Na	452,454–459,1737*,1865*
	NH_3	c(2×2)–N	1137
		c(2×2)–Na	
	NO	(1×1)	767,663,812
		*c(2×2)–N+O	767,812*
		c(2×2) streaked	663
		(2×2)	767,812
		Disordered	779
	O_2	*!(2×2)–O	2,49,50,51,198
			296–299,310,766
			978,1095,1138
			1168,1195,1356
			1358,1364,1417
			1732*,1738!,1743!
		*!c(2×2)–O	2,6,52–57,197*,198
			290–299,310,340,640
			766,978,1044,1095
			1138,1168,1195
			1220,1356,1358
			1417,1441,1565

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
			1738!,1739!,1740!,1741!, 1742!,1743!,1793!
		(2×1)–O	198
		NiO(100)	6,297,298,299,310
		NiO(111)	298,299
		Disordered	1291
	O(a)+CO	c(2×2)–C,O	1356
	P	$(\sqrt{5}\times\sqrt{5})R26.7°$–P	773,1644
		$\begin{pmatrix}1 & -1\\ 2 & 3\end{pmatrix}$–P	773
		$\begin{pmatrix}1 & -1\\ 2 & 1\end{pmatrix}$–P	773
	Pb	$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	471
		$\begin{pmatrix}1 & 1\\ -2 & 3\end{pmatrix}$	471
		$(5\sqrt{2}\times\sqrt{2})R45°$–Pb	773
	Si	c(2×2)–Si	1644
		$(2\sqrt{2}\times\sqrt{2})R45°$–Si	1644
	Sn	c(2×2)–Sn	773
	SO_2	c(2×2)–SO_2	86
		(2×2)–SO_2	86
	S,C	(1×1)	1561
	Te	*(2×2)–Te	197,198,306,1119 1732*
		*c(2×2)–Te	197,198,294,305 340,1119,1231 1597,1744*
		(2×1)–Te	198
		c(4×2)–Te	305,306
	Xe	Partially Ordered	1268
$Ni_3Al(001)$	[clean]	*(1×1)	1868*
NiCu(100) (Ni<50%)	S	c(2×2)–S	905
Ni–24% Fe(100)	O_2	c(2×2)–O	573
Ni–25% Fe(100)	H_2S,H_2	c(2×2)–S	1121
Ni–41% Fe(100)	[clean]	(1×1)	1263
	O_2	c(2×2)–O	1263
		Oxide	1263
NiO(100)	[clean]	*(1×1)	755,894,1638*
	Cl_2	Disordered	309
	H_2	Adsorbed	307
		Ni(100)	307
		(1×1)	894
		Coincidence	894
		(2×2)	894
	H_2S	Ni(100)–c(2×2)–S	308
	S	c(2×2)–S	1185
	SO_2	Disordered	1583

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Pb(100)	O_2	PbO(100)	1691
Pd(100)	[clean]	*(1×1)	1797*
	Ag	(1×1)	473,1797*
	Au	(1×1)	473,1806,1807
	C	c(4×2)–C	762
	CO	Disordered	70
		c(4×2)–CO	70
		c(2×2)–CO	210
		(2×4)R45°–CO	71,209,210
		c(2$\sqrt{2}$×$\sqrt{2}$)R45°–CO	1276,1294
		*(2$\sqrt{2}$×$\sqrt{2}$)R45°–2CO	910,1797*
		Incommensurate	1276
		Hexagonal Overlayer	209,210
	Cu	(1×1)	862
	Fe	Fe(100) and Fe(110)	452
	H_2	c(2×2)–H	595,919,1163,1454
		(1×1)–H	919
	H(a)+O_2	Adsorbed	1163,1454
	H_2+O_2	Disordered	1163
		(2×2)–O,H	1163
	H_2S	(2×2)–S	1294
		*c(2×2)–S	1294*
	Kr	Liquid-like	913
	Ni	(1×1)	1805
	NO	(2×2)	910
	O_2	(2×2)–O	596,597,891,939 1163,1334,1454
		c(2×2)–O	596,682,939,1334
		(2×2)+(7×7)–O	682
		(5×5)–O	596,1334
		($\sqrt{5}$×$\sqrt{5}$)R27°	596,1334
		Oxide	1334
		Hexagonal	1334
		Disordered O_2	1454
	O(a)+CO	Disorderd	939
	O(a)+H_2O	(2×1)–OH	940
	O(a)+H_2	Not Adsorbed	1163,1454
		(2×2)	1454
	Xe	Hexagonal Overlayer	311
		Liquid-like	913
		Island	913
Pt(100)	[clean]	(5×20) or "hex"	862,946,1265,1394
		*!(1×1)	1265,1293*,1394 1745*,1798!
		(1×5)	1265,1394,1171
	Au	$\begin{pmatrix} 14 & 1 \\ -1 & 5 \end{pmatrix}$	671
		(1×1)–Au	671
		(1×5)–Au	671
		(1×7)–Au	671
	C	Ring Pattern	762

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	C_2N_2	(1×1)	433
	CO	c(4×2)–CO	28,72,73,120,314 316,663,952,1307
		$(3\sqrt{2}\times\sqrt{2})$R45°–CO	28,72,73,316
		$(\sqrt{2}\times\sqrt{5})$R45°–CO	72,73
		(2×4)–CO	10
		(1×3)–CO	10
		(1×1)–CO	120,312,314,316 663
		c(2×2)–CO	312,316,928,1059 1252,663
		Reconstructed hex (or 5×20)	1059
	$CO+H_2$	c(2×2)–$CO+H_2$	72,74
	$CO+O_2$	(1×1) Diffuse	909
		c(2×2)–CO+(3×1)–O	928
	Cu	(1×1)	862
	F_2	(1×1)–F	886
	H_2	Adsorbed	312,317
		(2×2)–H	72,74
		Not Adsorbed	312
		(1×1)–H	582
	H_2O	Not Adsorbed	1258
	H_2O+HBr	$c(2\sqrt{2}\times\sqrt{2})$R45°–Br,HBr	1258
	H_2S or S_2	(2×2)–S	225,226,247,320
		c(2×2)–S	225,226,247,320,321
	HBr	$c(2\sqrt{2}\times\sqrt{2})$R45°–(Br+HBr)	806,1258
	Br,HBr(a)+H_2O	Not Adsorbed	1258
	Br,HBr(a)+NH_3	No Affinity	1258
	HCl	(2×2)–(Cl+HCl)	806
	HI	$c(\sqrt{2}\times\sqrt{2})$R45°–I	580
		c(2×4)–I	774
		Ring Pattern	774
		$c(2\sqrt{2}\times n\sqrt{2})$R45°, $n\geq 7$	774
		$c(2\sqrt{2}\times\sqrt{2})$R45°–I	774
	I_2	$c(\sqrt{2}\times\sqrt{2})$R45°–I	580
		Incommensurate–I	1390
		$c(\sqrt{2}\times 5\sqrt{2})$R45°–I	1390
		$c(\sqrt{2}\times 2\sqrt{2})$R45°–I	1390
		Hexagonal Overlayer	1390
		c(2×4)	1390
		$(\sqrt{7}\times\sqrt{7})$R19.1°–I	1390
	I(a)+Ag	$(\sqrt{2}\times\sqrt{2})$R45°–I,Ag	1390
		$(10\sqrt{2}\times 10\sqrt{2})$R45°–I,Ag	1390
		$(\sqrt{34}\times\sqrt{34})$R31°–I,Ag	1390
	N	Disordered	228
	NH_3	Poorly Ordered	1258
	NO	(1×1)–NO	318
		c(4×2)–NO	319
		(5×1)–NO	826
		c(2×4)–NO	826
		(1×1)+c(2×4)	946
	NO_2	(1×1)–N,NO	881
		(5×20)–NO_2	881

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	O_2	Not Adsorbed	120,312
		Adsorbed	312,315
		$(2\sqrt{2}\times2\sqrt{2})R45°$–O	215,313
		$PtO_2(0001)$	215
		(5×1)–O	315
		(5×1)+(1×1)–O	708,1171
		$(2\sqrt{2}\times\sqrt{2})R45°$–O	708
		(2×1)–O	315
		(3×1)–O	928,1014
		Complex	1014
	SO_2	(1×1) Diffuse	1258
	SO_2(a)+NH_3	(1×1) Diffuse	1258
Pt_3Ti(100)	[clean]	c(2×2)	935
Rh(100)	[clean]	*(1×1)	895,1024,1348 1800*
		(2×2)	1147
	Ag	(1×1)–Ag	895
		Complex [Multilayer]	895
	CO	Hexagonal Overlayer	231
		(4×1)–CO	58
		c(2×2)–CO	231,1348
	CO(a)+D_2	Compressed (CO)	1348
	CO_2	c(2×2)–CO	231
		Hexagonal Overlayer	231
	D_2	(1×1)–D	1348
	D(a)+CO	c(2×2)	1348
	Fe	Fe(100) and Fe(110)	452
	H_2	Adsorbed	231
	H_2S or S	c(2×2)–S	1403
		*(2×2)–S	742*,1403,1473
	N_2O	(2×2)	801
	NO	c(2×2)–NO	231
		Disordered	1024
	NO+D_2	Disordered	1025
	O_2	(2×2)–O	231,1403
		c(2×2)–O	231
		c(2×2)	801
		c(2×8)–O	58
		(3×1)	1403
Si(100)	[clean]	*!(2×1)	848,980,1017 1019,1084!,1207 1222,1428,1451,1477 1494,1483,1505 1514,1517,1523 1535,1547,1549 1645,1746*
		(2×2)	1579
		c(4×2)	1600
	Ag	(2×1)	923
		Ag(111)	1352
	Au	Au(111)	Si(100)

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Ge	(2×1)	1483
	H	(1×1)-H	325
		(2×1)-H	325
	H_2	(1×1)-H	322,323,324
			633,680
			1494
		(1×1)-2H	848,999,1222,1477,1488,1535
		(2×1)-H	237,848,999
			1222,1477,1488,1489
			1494,1535
	H_2O	(2×1)	1477
		Adsorbed	903
	I_2	(3×3)-I	326
	In	(2×1)-In	971
		(4×3)-In	971
		(1×1)-In	971
	K	(2×1)-K	1184
	N	Not Ordered	1230
	NH_3	(111) facets	238
	Ni	$NiSi_2(100)$	854,1659
	O_2	(1×1)-O	17,18,20
	Pd	Pd_2Si (Not Epitaxial)	1134
		(2×1)	1207
		(111) facets	17,18,20
	PH_3	(2×1)	1451
	Sb	(1×1)-Sb	1019
	Si	(1×1)	1517
	Si+laser	(2×1)	1392
	Sn	c(4×4)-Sn	959
		(6×2)-S	959
		c(8×4)-Sn	959,971
		(5×1)-Sn	959,971
		(2×1)-Sn	959
		(1×1)-Sn	959
SiC(100)	[clean]	(1×1)	1450
$SmB_6(001)$	[clean]	(2×2)	738
		(3×3)	738
Sn(100)	[clean]	(2×1)	1421,1497,1513
	H_2	(2×1)	1497,1513
Sr(100)	O_2	SrO(100)	327
$SrTiO_3(100)$	O_2	(1×1)	1672
		(2×2)	1672
		(2×1)	1672
	Ga	(3×2)-Ga	800
		(5×2)-Ga	800
		(2×2)-Ga	800
		(8×1)-Ga	800,809
Ta(100)	[clean]	*(1×1)	966,1219*
	Au	Split $\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	506,507
	CO	c(3×1)-O	328

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	CO_2	c(3×1)–O	328
	H_2	(1×1)	1219
	I_2	Amorphous	1180
		c(2×10)	1180
		c(2×2)	1180
	N_2	Adsorbed	328
	NO	c(3×1)–O	328
	O_2	·(2×8/9)–O	328
		c(3×1)–O	328
		(4×1)–O	328
		(3×3)–O	873
		(1×2)–O	873
		*(1×3)–O	873*
	Th	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	510,511
		(1×1)	510,511
Th(100)	CO	Disordered	329
	O_2	Disordered	329
		ThO_2	329
TiC(001)	[clean]	(1×1)	1631
	O_2	Disordered	611
UO_2(100)	[clean]	c(2×2)	648
V(100)	[clean]	*(1×1)	1126,1315*,1498
	Br_2	(1×1)–Br	651
		(5×1)–Br	1126
		c(2×2)–Br	1126
		(6×4)–Br	1126
		Ring Pattern	1126
	CO	(5×1)–O	1315
	H_2	Disordered	65
	O_2	(1×1)–O	65,651
		(2×2)–O	65
		(5×1)–O	1315
	O	(5×1)	1126
	S	c(2×2)–S	650,1315
		(1×1)–S	650
		(5×1)	650
		$(\sqrt{2}\times\sqrt{5})R27^\circ$–S	1315
W(100)	[clean]	*c(2×2)	749,1147,1340 1347,1388,1396 1503,1668*
		(2×2)	1340
		*(1×1)	1340,1347,1396 1471,1656,1763*,1802*
	Ag	(2×1)	546
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	546
		(1×1)	546
	Au	(2×1)	546

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	546
		(1×1)	546
	Ba	$\begin{pmatrix} 2 & 0 \\ -8 & 2 \end{pmatrix}$	531,532
		split $\begin{pmatrix} 1 & 1 \\ -2 & 2 \end{pmatrix}$	531,532
		$\begin{pmatrix} 1 & 1 \\ -2 & 2 \end{pmatrix}$	531,532
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	531,532
		c(4×2)–Ba	735
		c($2\sqrt{2}\times\sqrt{2}$)–Ba	735
		c($\sqrt{6}\times\sqrt{2}$)R45°–Ba	735
		c($2\sqrt{2}\times 2/3\sqrt{6}$)R45°–Ba	735
		(2×12)–Ba	994
		(2×10)–Ba	994
		(3×2)–Ba	994
		(3×2)+c(2×2)	994
		c(2×1.86)	994
		(10×21)–Ba	994
		c(2×2)–Ba	1399
		c(2×k) ($1.86 \leq k \leq 2\sqrt{2/3}$)	994
		Hexagonal	994
	Bi	c(2×2)	1260
		(2×2)	1260
		(1×1)	1260
	Br_2	c(2×2)	604
		($0.75\sqrt{2}\times\sqrt{2}$)R45°	604
		c(4×2)	604
		(5×2)	604
		c(6×2)	604
		(7×2)	604
		c(8×2)	604
	C	(5×1)–C	821
	Cl_2	c(2×2)	643
		c(4×1)	644
		(1×1)	644
		$\begin{pmatrix} -7 & 1 \\ 1 & 1 \end{pmatrix}$–Cl	733
		$\begin{pmatrix} -5 & 1 \\ 1 & 1 \end{pmatrix}$–Cl	733
		($3\sqrt{2}\times\sqrt{2}$)R45°–Cl	733
	CO+N_2	(4×1)–CO+N_2	82
	CO	Disordered	75
		*c(2×2)–CO	66,75,1465*
		c(2×2)–C+O	777

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	CO_2	Disordered	338
		(2×1)–O	338
		c(2×2)–CO	338
	Cs	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	523,524,525,526
		(2×2)	523,524,525,526
		Split (2×2)	523,524
		Hexagonal	525,526
	Cu	(2×2)	543
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	543
	Ga	(1×1)–Ga	789
	H_2	c(2×2)–H	66,78,79,337,411 712,771,1275,1347 1361,1388,1603 1668
		$(\sqrt{2}\times\sqrt{2})$–H	834,1032,1511
		Incommensurate $(\sqrt{2}\times\sqrt{2})$–H	1032
		1 dim order	1032
		(2×5)–H	79
		(4×1)–H	79
		(1×1)–(2)H	411,771,897*,1032,1165 1347,1388,1747*
		(2×2)–H	1361
		Incommensurate	834,1511
		Disordered	771,834
	H_2S	(2×1)	821
		c(2×2)–S	887
	Hg	(1×1)	549
	K	$\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$	1841
	N_2	*c(2×2)–N	68,82,131,776 1099,1465*,1748*
		Contracted Domain	1609
	N_2O	(1×1)–N_2O	143
		(4×1)–N_2O	143
	Na	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	1840
	NH_3	Disordered	84
		c(2×2)–NH_2	84
		c(2×2)–N	1099
		(1×1)–NH_2	84
	NO	(2×2)–NO	339
		(4×1)–NO	339
		(2×2)–O	339
		(4×1)–O	339
		(2×1)–O	339

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	O_2	*Disordered	330,1749*
		(4×1)–O	66,330–333,336,821 1058
		(2×2)–O	330–334
		(2×1)–O	66,67,330–336,821,1058
		(3×3)–O	331,333,335
		c(2×2)–O	333
		c(8×2)–O	333
		(3×1)–O	333
		(1×1)–O	333
		(8×1)–O	333
		(4×4)–O	333,335
		(110) facets	333
	O_2+H_2	$(\sqrt{2}\times\sqrt{2})$+(4×1)–O,H	815
	Pb	Disordered (2×2)	550
		Split $\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	550
		$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	550,551
		$\begin{pmatrix}1 & 1\\ -2 & 2\end{pmatrix}$	550
		Hexagonal	550
		(2×2)	551
		$\begin{pmatrix}2 & 0\\ -1 & 2\end{pmatrix}$	551
		(1×1)	551,702
		c(4×2)–Pb	702
		c(2×2)–Pb	702
	Pd	$(2\sqrt{2}\times\sqrt{2})R45°$–Pd	646
		(2×1)–Pd	646
		c(2×2)–Pd	646
	Rb	$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	522
		(2×2)	522
		Hexagonal	522
	S	(2×2)–S	1324
		(3×3)–S	1324
		(4×2)–S	1324
		(2×1)–S	1324
		(5×5)–S	1324
	Sb	(2×2)	553,554
		$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	553,554
		(1×1)	553,554

TABLE IV. Surface Structures on Substrates with Four-fold Rotational Symmetry (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Se	(2×1)	1326
		(8×1)	1326
		(6×1)	1326
		(3×1)	1326
		c(2×2)	1326
	Sn	(1×1)–Sn	789
		c(2×2)–Sn	789
	Te	(3×3)–Te	1323
		(2×2)–Te	1323
		Complex	1323
		(2×1)–Te	1323
	Th	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	556–560
		(1×1)	556–560
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	559,560
		Hexagonal	559,560
	Rb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	522
		(2×2)	522
		Hexagonal	522
	Zr	(1×1)	541,764,789
		$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	541
		c(2×2)	764,789
$WO_3(100)$	[clean]	split (1×1)	991
		(5×1)	1393
		$(\sqrt{2}\times\sqrt{2})R45°$,(5×1)	1393
Xe(100)	[clean]	*(1×1)	1914*

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces

Substrate	Adsorbate	Surface Structure	Reference
Ag(100)	Au	(1×1)	1806
	Cu	Epitaxial	1167
		Cu(100)	1476
		(1×1)	1820
	Fe	(1×1)	1272
	Ni	(1×1)	1820
	Pd	Epitaxial	1167
		(1×1)	1463
Ag(110)	Cs	(1×2)	859,1534
		(1×3)	859,1534
	K	(1×2)	1534
		(1×3)	1534
	Li	(1×2)	1534
	Na	(1×1)	489
Ag(111)	Al	Disordered	491
	Au	(1×1)	491,1355,1825 1826
	Bi	Disordered	491
	Cd	No Condensation	491
	Co	Disordered	491
	Cr	Disordered	491
	Cu	Hexagonal Overlayer	1822–1824
	K	Hexagonal Overlayer	1345
	Mg	Disordered	491
	Na	(1×1)	488
	Ni	Hexagonal Overlayer	491,1821
	Pb	$(\sqrt{3}\times\sqrt{3})R30°$–Pb	975
		Pb(111)	975
		Hexagonal Overlayer	491,1827
	Pd	(1×1)	1463
		Disordered	491
	Rb	(1×1)–Rb	490,705
		(9×9)	705
	Sb	Disordered	491
	Sn	Disordered	491
	Tl	Hexagonal Overlayer	491
	Zn	No Condensation	491
Al(100)	Ag	(5×1)–Ag	1363
		(1×1) [Multilayer]	1363
	Au	Disordered	1363
	Cu	Disordered	1363
	Fe	Poor Epitaxy	452
	Na	*c(2×2)	499,500,501*,1926*
		Hexagonal Overlayer	500
	Pb	$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	503
		c(2×2)–Pb	704
		$\begin{pmatrix} 2 & 0 \\ 1 & n \end{pmatrix}$–Pb $2<n<3$	704

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Sm	(1×1) Disorder	1532
		Complicated	1532
	Sn	$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	503
		c(2×6)–Sn	704
		$\begin{pmatrix} 2 & 0 \\ 1 & n \end{pmatrix}$ $2<n<3$	704
Au(100)	Ag	(1×1)	473,474,494,1838
	Bi	$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	498
	Cu	(1×1)	473
	Fe	(1×1)	1828–1830
	Na	Hexagonal	492
		Ordered	492
	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	441–444
		$\begin{pmatrix} 1 & 1 \\ -3 & 4 \end{pmatrix}$	441–444
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	441–444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	441–444
		(1×1)	683
	Pd	(1×1)	473,1833
		c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
	Pt	(1×1)	438,439,440
Au(110)	Bi	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	498
		$\begin{pmatrix} 2 & 1 \\ -1 & 1 \end{pmatrix}$	498
		(2×1)	498
	Pb	(1×3)	444,495,683
		(1×1)	444,495,683
		(7×1)	444,495,683
		(7×3)	444,495,683
		(4×4)	444,495,683

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Au(111)	Ag	(1×1)	491,1825
		fcc(111)	1689
	Ag,Air	$Ag_2O(110)$–(2×1)	997
	Bi	$\begin{pmatrix} 10 & 10 \\ -10 & 20 \end{pmatrix}$	498
		(2×2)	924
	Cr	Hexagonal	493
	Cu	$(\sqrt{3}\times\sqrt{3})R30°$–Cu	861,1558,1582
		(1×1)	1558
		Extra Lines(RHEED)	1836,1837
	Fe	(1×1)	1828,1830–1832
	Pb	Hexagonal Rotated ± 5°	444,495
		$(\sqrt{3}\times\sqrt{3})R30°$	924
		(1×1)	683
	Pd	(1×1)	1807,1834
	Pt	(1×1)	1835
Au(311)	Pb	(5×3)	496
		(3×3)–Pb	730
		(3×4)–Pb	730
Au(511)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ 1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(711)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(911)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(11,1,1)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
Au(210)	Pb	(1×1)	497
Au(320)	Pb	(3×3)	496
		(1×1)-Pb	730
Cr(111)	Ag	(8×8)	46
	Au	$\begin{pmatrix} \frac{2}{3} & 3 \\ \frac{-2}{3} & \frac{4}{3} \end{pmatrix}$	52
	Bi	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	61
		$\begin{pmatrix} 2 & -1 \\ 0 & 2 \end{pmatrix}$	61
		$\begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix}$	61
	Fe	(1×1)	39
	Ni	(1×1)	43,44
	Pb	(4×4)	55,58
	Sn	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	54
Cu(100)	Ag	$\begin{pmatrix} 2 & 0 \\ -1 & 5 \end{pmatrix}$	473,477
	Au	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	473,478
		$\begin{pmatrix} 2 & 0 \\ -1 & 7 \end{pmatrix}$	473,478
	Bi	(2×2)	483,486
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	483,486
		$\begin{pmatrix} 1 & 1 \\ -4 & 5 \end{pmatrix}$	483,486
		$\begin{pmatrix} 5 & 4 \\ -4 & 5 \end{pmatrix}$	483,486
		(1×1)	703
		c(2×2)	703

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Co	(1×1)–Co	983,1105,1810 1811
	Cs	Hexagonal Overlayer	865
		Quasi-Hexagonal	865
		Disordered	865
	Fe	(1×1)	452,1808,1809
	K	$\begin{pmatrix} 2 & 3 \\ 0 & 5 \end{pmatrix}$	1405
		$\begin{pmatrix} 2 & 2 \\ 0 & 3 \end{pmatrix}$	1405
		Incommensurate	1405
	Mn	c(2×2)–Mn	1319
	Nb	Incommensurate	667
	Ni	(1×1)	1812
	Pb	$\begin{pmatrix} 2 & 2 \\ -2 & 2 \end{pmatrix}$	481–485
		$\begin{pmatrix} 1 & 1 \\ -2 & 3 \end{pmatrix}$	481–485
		*c($5\sqrt{2}\times\sqrt{2}$)R45°–Pb	703,1295*
		*c(2×2)–Pb	1295*
		($2\sqrt{2}\times2\sqrt{2}$)R45°–Pb	1295
	Pd	c(2×1)–Pd	726
		(1×1)–Pd	726,1649
		c(2×2)–Cu_3Pd	1649
	Sn	(2×2)	480
	Te	*!(2×2)–Te	267*,1119,1728!
	Tl	$\begin{pmatrix} 2 & 2 \\ 2 & -2 \end{pmatrix}$	1167,1564
		$\begin{pmatrix} 4 & 0 \\ 2 & 7 \end{pmatrix}$–Tl	1167,1336,1564
		$\begin{pmatrix} 4 & 0 \\ 2 & 6 \end{pmatrix}$–Tl	1336,1564
		$\begin{pmatrix} 6 & 6 \\ 2 & -2 \end{pmatrix}$	1564
		c(4×4)–Tl	1336
Cu(110)	Au	$\begin{pmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{3}{2} \end{pmatrix}$	479
		(1×2)	479
		(2×2)	479
	Pb	$\begin{pmatrix} 1 & 1 \\ -1 & 1 \end{pmatrix}$	481,482

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		(5×1)	481,482
		(4×1)	482
	Pd	(2×1)–Pd	726
		(1×1)–Pd	726
Cu(111)	Ag	(8×8)	477
		3 Dimensional Crystals	1813,1815–1818
		(1×1)	1526
	Au	$\begin{pmatrix} \frac{2}{3} & \frac{2}{3} \\ -\frac{2}{3} & \frac{4}{3} \end{pmatrix}$	479
		(2×2)	479
		3 Dimensional Crystals	1815,1819
	Bi	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	487
		$\begin{pmatrix} 2 & -1 \\ 0 & 2 \end{pmatrix}$	487
		$\begin{pmatrix} 2 & 3 \\ 1 & 2 \end{pmatrix}$	487
	Co	(1×1)–Co	1299
	Cs	*(2×2)–Cs	711,1430*
	Fe	(1×1)	474
	Na	(2×2)–Na	1571
	Ni	*(1×1)–Ni	475,476,1466*
			1813
	Pb	(4×4)	481,484
	Pd	(1×1)	726,1538
	Sn	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	480
Cu(211)	Pb	(4×1)	484
Cu(311)	Pb	$\begin{pmatrix} 3 & 1 \\ -2 & 1 \end{pmatrix}$	484
		(4×2)	484
Cu(511)	Pb	(4×1)	482
Cu(711)	Pb	(4×1)	482,484
Fe(100)	K	Disordered	665
		(2×2)–K	784
		Hexagonal Close Pack	784
Fe(110)	K	Hexagonal Array	728
Fe(111)	K	(3×3)–K	665,1350
Ge(111)	Al	(2×1)	1550
	Au	$(\sqrt{3}\times\sqrt{3})R30°$–Au	1223
Ir(100)	Ba	(2×1)–Ba	1399
	Cs	c(4×2)–Cs w.Streak	1395
		Close Packed Layer	1395

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		Compressed Layer	1395
		(5×5)–Cs	1395
	K	$c(2\sqrt{2}\times 4\sqrt{2})R45°$	866
		$\begin{pmatrix} 2 & 1 \\ -1 & 2 \end{pmatrix}$	866
		c(4×2)	866
		(3×2)	866
		c(2×2)	866
		$\begin{pmatrix} \frac{5}{2} & 0 \\ \frac{-5}{4} & \frac{5}{3} \end{pmatrix}$	866
		$\begin{pmatrix} 2 & 0 \\ -1 & \frac{5}{3} \end{pmatrix}$	866
		$\begin{pmatrix} \frac{10}{7} & 0 \\ \frac{-5}{7} & \frac{5}{3} \end{pmatrix}$	866
Ir(111)	Au	(1×1)	453
	Cr	Hexagonal	453
Mo(100)	Ag	Ag(100)	513,514
		Ag(110)	513,514
	Cs	$(\sqrt{2}\times\sqrt{2})R45°$	932
		(2×2)	932
		c(2×2)	932
		Rectangular Centered Mesh	932
		Quasi Hexagonal	932
		Hexagonal Overlayer	932
	Ga	(1×1)–Ga	789
	Sn	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	516
		(1×2)	516
		(1×1)–Sn	789
		c(2×2)–Sn	789
Mo(110)	Al	Hexagonal	515
	Au	Disordered	1681
	Cs	Hexagonal	512
	K	Hexagonal	512
	Na	No Ordered Structure	512
	Rb	Hexagonal	512
Mo(211)	Ba	(1×5)	1591,1675
		(4×2)	1591
	Cs	$c(2\times 1/J), 0.15<J<0.64$	1590
		c(2×2)	1590
	La	Linear Chains	1447
		c(2×2)	1447
		c(2×4/3)	1447

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Li	(1×4)–Li	1593
		(1×2)–Li	1593
		(1×1)–Li	1593
	Na	(1×4)–Na	1684
		(1×3)–Na	1684
		(1×2)–Na	1684
		(1×3/2)–Na	1684
	Sr	(1×9)–Sr	1594
		(1×5)–Sr	1594
		(4×2)–Sr	1594
Nb(110)	Sn	Disordered	505
		(3×1)	505
Ni(100)	Ba	Disordered	454
	Co	(1×1)	1803
	Cr	(1×1)	463,464
	Cs	(2×2)	454
		Hexagonal	463,464
	Cu	*(1×1)–Cu	1113,1458*,1804
	Fe	c(2×2)–Fe	973
		Fe(110)	452,973
	K	(4×2)	454
	Na	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	452,454–459
		*c(2×2)–Na	1737*,1865*
	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	471
		$\begin{pmatrix} 1 & 1 \\ -2 & 3 \end{pmatrix}$	471
		$(5\sqrt{2}\times\sqrt{2})R45^\circ$–Pb	773
	Sn	c(2×2)–Sn	773
Ni(110)	Cs	Disordered	455
	K	Disordered	455
	Na	Disordered	455,458,460
		Hexagonal	455,458,460
	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	471
		(3×1)	471
		(4×1)	471
		(5×1)	471
	Yb	(2×1)–Yb	844
Ni(111)	Ag	(6×6)	465,466
	Au	(6×6)	467,468,469,470
		(13×13)	467,468,469
	Bi	$(\sqrt{3}\times\sqrt{3})R30^\circ$–Bi	864
		(7×7)–Bi	864
		$(\sqrt{7/4}\times\sqrt{7/4})R19^\circ$–Bi	864
	Mo	(5×5)	447,448
		(4×4)	447,448

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 2 & 0 \\ 5 & 10 \end{pmatrix}$	447,448
		$\begin{pmatrix} 1 & 0 \\ 5 & 10 \end{pmatrix}$	447,448
	Na	Hexagonal	455,458,460
	Pb	$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	471,472
		(7×7)	471,864
		(13×13)	471,472
		(3×3)	471,864,1060
		(4×4)–Pb	864,1060
		Hexagonal Rotated ± 3°	472
		$(\sqrt{3}\times\sqrt{3})R30°$–Pb	864,1060
	Sn	(2×2)–Sn	1060
		$(\sqrt{3}\times\sqrt{3})R30°$–Sn	1060
	Te	$(2\sqrt{3}\times2\sqrt{3})R30°$–Te	577
Pd(100)	Ag	*(1×1)	473,1797*
	Au	(1×1)	473,1806,1807
	Cs	*(1×2)+Disordered C_s	1760*
	Cu	(1×1)	862
	Fe	Fe(100) and Fe(110)	452
	Na	*(1×2)+Disordered Na	1760*
	Ni	(1×1)	1805
Pd(111)	Au	!(1×1)–Au	1709!
	Fe	(1×1)	1546
Pt(100)	Au	$\begin{pmatrix} 14 & 1 \\ -1 & 5 \end{pmatrix}$	671
		(1×1)–Au	671
		(1×5)–Au	671
		(1×7)–Au	671
Pt(111)	Ag	Disordered	1254
	Au	Disordered	1254
	Cu	(1×1)–Cu	842
		Cu(111) Multilayers	842
		Alloy Formation	842
	K	$(\sqrt{3}\times\sqrt{3})R30°$–K	1071,1238,1337
		$\begin{pmatrix} 1.66 & 0 \\ 0 & 1.66 \end{pmatrix}$–K	1337
		"Ring" Pattern	1337
Re(0001)	Ba	(2×2)	565,566
		Hexagonal	565,566
Re(10$\bar{1}$0)	Ba	c(2×2)	1591
	Mg	(1×3)	1675

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Rh(100)	Ag	(1×1)	895
		Complex	895
	Fe	Fe(100) and Fe(110)	452
Ru(0001)	Cu	Disordered	1679
	Na	(3/2×3/2)–Na	1129,1406
		Ring Pattern	1129
		(2×2)–Na	1082,1129
		$(\sqrt{3}\times\sqrt{3})R30°$–Na	1082,1129,1406
		Hexagonal Overlayer	1406
Sb(0001)	Fe	(1×1)	567
	Th	$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	510,511
		(1×1)	510,511
Ta(110)	Al	Hexagonal	508,509
		Square	508,509
Ti(0001)	Cd	*(1×1)	562*,563,564
	Cu	Extra Spots	561
W(100)	Ag	(2×1)	546
		$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	546
		(1×1)	546
	Au	(2×1)	546
		$\begin{pmatrix}2 & 0\\ -1 & 2\end{pmatrix}$	546
		(1×1)	546
	Ba	$\begin{pmatrix}2 & 0\\ -8 & 2\end{pmatrix}$	531,532
		split $\begin{pmatrix}1 & 1\\ -2 & 2\end{pmatrix}$	531,532
		$\begin{pmatrix}1 & 1\\ -2 & 2\end{pmatrix}$	531,532
		$\begin{pmatrix}1 & 1\\ 1 & -1\end{pmatrix}$	531,532
		c(4×2)–Ba	735
		$c(2\sqrt{2}\times\sqrt{2})$–Ba	735
		$c(\sqrt{6}\times\sqrt{2})R45°$–Ba	735
		$c(2\sqrt{2}\times 2/3\sqrt{6})R45°$–Ba	735
		(2×12)–Ba	994
		(2×10)–Ba	994

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		(3×2)–Ba	994
		(3×2)+c(2×2)	994
		c(2×1.86)	994
		(10×21)–Ba	994
		c(2×2)–Ba	1399
		c(2×K),(1.86≤K≤$2\sqrt{2/3}$)	994
		Hexagonal	994
	Bi	c(2×2)	1260
		(2×2)	1260
		(1×1)	1260
	Cs	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	523,524,525,526
		(2×2)	523,524,525,526
		Split (2×2)	523,524
		Hexagonal	525,526
	Cu	(2×2)	543
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	543
	Ga	(1×1)–Ga	789
	Hg	(1×1)	549
	K	$\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$	1841
	Na	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	1840
	Pb	Disordered (2×2)	550
		Split $\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	550
		$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	550,551
		$\begin{pmatrix} 1 & 1 \\ -2 & 2 \end{pmatrix}$	550
		Hexagonal	550
		(2×2)	551
		$\begin{pmatrix} 2 & 0 \\ -1 & 2 \end{pmatrix}$	551
		(1×1)	551,702
		c(4×2)–Pb	702
		c(2×2)–Pb	702

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	Pd	$(2\sqrt{2}\times\sqrt{2})R45°$–Pd	646
		(2×1)–Pd	646
		c(2×2)–Pd	646
	Rb	$\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$	522
		(2×2)	522
		Hexagonal	522
	Sb	(2×2)	553,554
		$\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$	553,554
		(1×1)	553,554
	Sn	(1×1)–Sn	789
		c(2×2)–Sn	789
	Th	$\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$	556–560
		(1×1)	556–560
		$\begin{pmatrix}2 & 0\\-1 & 3\end{pmatrix}$	559,560
		Hexagonal	559,560
	Rb	$\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$	522
		(2×2)	522
		Hexagonal	522
	Zr	(1×1)	541,764,789
		$\begin{pmatrix}2 & 0\\-1 & 2\end{pmatrix}$	541
		c(2×2)	764,789
W(110)	Ag	Hexagonal Structures	546,547
		Ag(111)	1151
	Au	Hexagonal Structures	546,548
	Ba	Disordered Hexagonal	533–535
		Hexagonal	533–535
		$\begin{pmatrix}2 & 2\\0 & 6\end{pmatrix}$	533–535
		$\begin{pmatrix}2 & 2\\0 & 5\end{pmatrix}$	533–535
		$\begin{pmatrix}3 & 3\\1 & 5\end{pmatrix}$	533–535
		Hexagonal Compact	533–535
	Be	(1×9)	529
		(1×1)	529

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 9 & 0 \\ -1 & 1 \end{pmatrix}$	529
	Cs	Disordered Hexagonal	523,527,528
		Hexagonal	523,527,528,1677
	Cu	Hexagonal	543–545
		Cu(111)	1151
	Fe	3-Dimensional Crystals	451
		Fe(110)	1325
		(1×1)	1325
	Li	$\begin{pmatrix} 1 & 5 \\ -2 & 2 \end{pmatrix}$	517–519
		(2×2)	517–519
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	517–519
		(2×3)–Li	1269
		c(2×2)–Li	1269
		c(3×1)–Li	1269
		c(1×1)–Li	1269
	Na	$\begin{pmatrix} 1 & 5 \\ -2 & 2 \end{pmatrix}$	445,446
		(2×2)	445,446
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	445,446
		$\begin{pmatrix} 1 & 1 \\ 0 & 8 \end{pmatrix}$	445,446
		$\begin{pmatrix} 1 & 1 \\ 0 & 5 \end{pmatrix}$	445,446
		Hexagonal	445,446
	Ni	(1×1)–Ni	970
		(8×2)–Ni	970
		(7×2)–Ni	970
	Pd	(1×3)	542
		Hexagonal	542
	Pb	Split $\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	551,552
		$\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	551,552
	Sb	$\begin{pmatrix} 1 & 1 \\ 0 & 4 \end{pmatrix}$	553,555
		$\begin{pmatrix} 2 & 0 \\ -1 & 1 \end{pmatrix}$	553,555

TABLE V. Surface Structures of Metallic Monolayers on Metal Crystal Surfaces (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix} 3 & 0 \\ -1 & 1 \end{pmatrix}$	553,555
		$\begin{pmatrix} 4 & 0 \\ -1 & 1 \end{pmatrix}$	553,555
	Sc	$\begin{pmatrix} 1 & 1 \\ 0 & 3 \end{pmatrix}$	536–538
		$\begin{pmatrix} 2 & 2 \\ 0 & 8 \end{pmatrix}$	536–538
	Sr	$\begin{pmatrix} 3 & 3 \\ -2 & 5 \end{pmatrix}$	530
		$\begin{pmatrix} 2 & 2 \\ 0 & 6 \end{pmatrix}$	530
		$\begin{pmatrix} 2 & 2 \\ 1 & 6 \end{pmatrix}$	530
		$\begin{pmatrix} 1 & 0 \\ 0 & 3 \end{pmatrix}$	530
	W	Ring Pattern	1623
	Y	Hexagonal	539,540
W(211)	Ag	(1×1)–Ag	969
	Au	(1×1)–Au	969
		(1×2)–Au	969
		(1×3)–Au	969
		(1×4)–Au	969
	Li	(4×1)	518,520
		(3×1)	518,520
		(2×1)	518,520
		Incoherent	518,520
		(1×1)	518,520
		[clean]	(2×2)
	Mg	(1×7)–Mg	1657
		(3×3)–Mg	1657
	Na	(2×1)	521
		Compressed(2×1)	521
	Sb	(2×1)	553
		(1×1)	553
W(221)	Na	Compressed(2×1)	521
		(2×1)	521
	Ni	(1×1)–Ni	970
		(6×1)–Ni	970
Zn(0001)	Cu	(1×1)	449,450

TABLE VI. Surface Structures of Alloys

Substrate	Adsorbate	Surface Structure	Reference
Ag(111)–Rb dosed	O_2	$(2\sqrt{3}\times2\sqrt{3})R30^\circ$–Rb/O	653
		(4×4)–Rb/O	653
		Complex Structures	653
		(9×9)–Rb/O	653
Cu–3% Al(100)	O_2	$c(2\times2)$–O	1632
		Disordered	1632
Cu–5.7% Al(100)	[clean]	(1×1)	813
Cu–12.5% Al(100)	[clean]	(1×1)	813
$Cu_3Al(100)$	[clean]	$c(2\times2)$	916
Cu/Al(111)	[clean]	(1×1)	835
		$(\sqrt{3}\times\sqrt{3})R30^\circ$	835
Cu–5.7% Al(111)	[clean]	(1×1)	813
Cu–10% Al(111)	[clean]	(1×1)	1303
		$(\sqrt{3}\times\sqrt{3})R30^\circ$–Al	1303
Cu–11% Al(111)	[clean]	*(1×1)	1506*
Cu–12.5% Al(111)	[clean]	$(\sqrt{3}\times\sqrt{3})R30^\circ$	813
Cu–16% Al(111)	[clean]	*$(\sqrt{3}\times\sqrt{3})R30^\circ$	1699*
Cu/Au(100)	[clean]	$c(2\times2)$	737
Cu/Au(110)	[clean]	Streak	737
		(1×2)	737
		Complex Pattern	737
		$c(3\times1)$	737
		$c(2\times2)$	737
Cu/Au(111)	[clean]	$(2/3\sqrt{3}\times2/3\sqrt{3})R30^\circ$	737
		(2×2)	737
Cu/Au$(1\bar{1}1)$	[clean]	$(2/3\sqrt{3}\times2/3\sqrt{3})R30^\circ$	737
		(2×2)	737
Cu(110)–Ni(1°)	O_2	(2×1)–O	1311
		$c(6\times2)$–O	1311
Cu/Ni(110)	CO	(2×1)–CO	134
		(2×2)–CO	134
		(1×2)–CO	787
	H_2	(1×3)–H	787
	H_2S	$c(2\times2)$–S	134
	O_2	(2×1)–O	134,872
		(2×2)–O	872
Cu/Ni(111)	CO	Disordered	173,734
Cu/Pd(100)	[clean]	Streak	737
		$c(2\times2)$	737
Cu/Pd(110)	[clean]	(2×1)	737
Cu/Pd(111)	[clean]	(1×1)	737
Cu/Pd$(1\bar{1}1)$	[clean]	(1×1)	737
CuSn(100)	[clean]	$c(2\times2)$	1481
		$(3\sqrt{2}\times\sqrt{2})R45^\circ$	1481
		$c(3\times2)+(2\times2)$	1481
Cu–25% Zn(100)	[clean]	(1×1)	1152
	O_2	Disordered	1152
Cu–25% Zn(110)	[clean]	(1×1)	1152
	O_2	Disordered	1152

TABLE VI. Surface Structures of Alloys (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Cu–25% Zn(111)	[clean]	(1×1)	1152
	O_2	Disordered	1152
Fe/Cr(100)	O_2	c(2×2)–O	279,636
		c(4×4)–O	279
		Oxide	280
Fe/Cr(110)	O_2	Cr_2O_3(0001)	280
		Amorphous Oxide	279
Fe–18% Cr–12% Ni(111)	[clean]	(1×1)	1249
	I_2	$(\sqrt{3}\times\sqrt{3})R30°$–I	1249
	H_2O	Ordered	1249
	O_2	Ordered	1249
	I(a)+H_2O	Oxide Not Formed	1249
	H_2O(a)+I_2	Adsorbed	1249
FeTi(100)	[clean]	(1×1)	1241
	S	c(2×2)–S	1241
FeTi(111)	[clean]	(1×1)	1241
Ni_3Al(001)	[clean]	*(1×1)	1868*
NiAl(110)	[clean]	*(1×1)	1771*
NiCu(100) (Ni<50%)	S	c(2×2)–S	905
Ni–17% Cu(111)	[clean]	(1×1)	868
	H_2	(2×2)–H	868
Ni–24% Fe(100)	O_2	c(2×2)–O	573
Ni–25% Fe(100)	H_2S,H_2	c(2×2)–S	1121
Ni–25% Fe(110)	H_2S,H_2	(2×3)–S	1121
Ni–25% Fe(111)	H_2S,H_2	(3×3)–S	1121
Ni–41% Fe(100)	[clean]	(1×1)	1263
	O_2	c(2×2)–O	1263
		Oxide	1263
Ni_4Mo(211)	[clean]	Ordered	1115
Pd–33% Ag(111)	[clean]	(1×1)	877
	CO	(1×1)	877
Pd–25% Cu(111)	[clean]	(1×1)	877
	CO	(1×1)	877
Pt–2% Cu(110)	[clean]	(1×3)	1062
	CO	(1×1)–CO	1063
Pt–22% Ni(111)	[clean]	(1×1)	1162
Pt–50% Ni(111)	[clean]	(1×1)	1162
Pt_3Ti(100)	[clean]	c(2×2)	935
Pt_3Ti(111)	[clean]	(2×2)	935

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules

Substrate	Adsorbate	Surface Structure	Reference
Ag(100)	$C_2H_4Cl_2$	*c(2×2)–Cl	154,249*,1873*
Ag(110)	C_2H_2	Not Adsorbed	812
	C_2H_4	Not Adsorbed	1690
	$C_2H_4+O_2$	(2×1)–O	1001
	$C_2H_4Cl_2$	(2×1)–Cl	154
		c(4×2)–Cl	154
	$O(a)+C_2H_2$	c(2×6)–acetylide	1335,1398
		(2×2)–acetylide	1335,1398
		(2×3)–acetylide	1335,1398
		(1×1)–C	1335
Ag(111)	CH_2Br_2	(1×1)	594
	CH_3I	$(\sqrt{3}\times\sqrt{3})R30°$–I	594
	$CHCl_3$	(1×1)	594
	$C_2H_4CL_2$	$(\sqrt{3}\times\sqrt{3})R30°$–Cl	153,154
		(3×3)–Cl	153,154
	Acetic Acid	$\begin{pmatrix}2 & -0.7\\ 2 & 2.7\end{pmatrix}+\begin{pmatrix}2.8 & 1.4\\ 0 & 2.5\end{pmatrix}$	587
		Ring Pattern	587
	Propanoic Acid	$\begin{pmatrix}4 & 2\\ 0 & 4.3\end{pmatrix}+\begin{pmatrix}3.9 & 1.3\\ 1 & 4.6\end{pmatrix}$	587
		$\begin{pmatrix}4 & 2\\ 0 & 4.3\end{pmatrix}$	587
Ag[3(111)×(100)]	CH_2Br_2	(1×1)	594
	CH_3I	$(\sqrt{3}\times\sqrt{3})R30°$–I	594
	$CHCl_3$	(1×1)	594
Al(100)	C_2H_4	(1×1)	1693
Au(111)	C_2H_4	Not Adsorbed	161
	benzene	Not Adsorbed	161
	cyclohexene	Not Adsorbed	161
	naphthalene	Disordered	161
	n-heptane	Not Adsorbed	161
Au(S)–[6(111)×(100)]	C_2H_4	Not Adsorbed	161
	benzene	Not Adsorbed	161
	cyclohexene	Not Adsorbed	161
	naphthalene	Disordered	161
	n-heptane	Not Adsorbed	161
C(0001), graphite	CH_4	$(\sqrt{3}\times\sqrt{3})R30°$	1018
	C_2H_6	$(4\times\sqrt{3})$–C_2H_6	1191
		(2×2)–C_2H_6	1191
		$(10\times2\sqrt{3})$–C_2H_6	1191
		$(\sqrt{3}\times\sqrt{3})$–C_2H_6	1191
Cr(100)	C_2H_4	c(2×2)–C	1245
		$(\sqrt{2}\times3\sqrt{2})R\pm45°$–C	1245
Cu(100)	C_2H_4	(2×2)	26
	O(a)+HCOOH	!Disordered–HCO_2	1921!,1922!
	$O(a)+CH_3OH$	!Disordered–CH_3O	1922!
	Cu-phtalocyanine	$\begin{pmatrix}5 & -2\\ 2 & 5\end{pmatrix}$	408

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	D-tryptophan	(4×4)	409
	Fe-phtalocyanine	$\begin{pmatrix} 5 & -2 \\ 2 & 5 \end{pmatrix}$	408
	glycine	(4×2)	409
/		$\begin{pmatrix} 8 & -4 \\ 0.8 & 1.6 \end{pmatrix}$	409
	H-phtalocyanine	$\begin{pmatrix} 5 & -2 \\ 2 & 5 \end{pmatrix}$	408
	L-alanine	$\begin{pmatrix} 2 & 1 \\ 2 & -1 \end{pmatrix}$	409
	L-tryptophan	(4×4)	409
	D-tryptophan	(4×4)	409
Cu(110)	C_2H_4	Ord. 1D	26
	HCOOH	!HCO_2–Disordered	1849!
Cu(111)	C_2H_4	Not Adsorbed	26
	Cu-phtalocyanine	Adsorbed	408
	D-tryptophan	$\begin{pmatrix} -8 & 1 \\ -2 & 4 \end{pmatrix}$	409
	Fe-phtalocyanine	Adsorbed	408
	glycine	(8×8)	409
	H-phtalocyanine	Adsorbed	408
	L-alanine	$(2\sqrt{13}\times2\sqrt{13})R13°40'$	409
	L-tryptophan	$\begin{pmatrix} 7 & 1 \\ -2 & 4 \end{pmatrix}$	409
Cu(S)–[3(100)×(100)]	CH_4	Not Adsorbed	132
	C_2H_4	Not Adsorbed	132
Cu(S)–[4(100)×(100)]	CH_4	Not Adsorbed	132
	C_2H_4	Not Adsorbed	132
Fe(100)	C_2H_4	c(2×2)–C	274,893
Fe(110)	C_2H_2	(2×2)	687
		(2×3)	687
		Coincidence	687
		$\begin{pmatrix} 4 & 0 \\ -1 & 3 \end{pmatrix}$	687
Fe(111)	C_2H_2	(1×1)	687
		(5×5)	687
		(3×3)	687
	C_2H_4	(1×1)	687
		(5×5)	687
		(3×3)	687
GaAs(110)	HCOOH	c(2×2)–H+HCOO	1124,1302
Ir(100)	C_2H_2	Disordered	281,410
		c(2×2)–C	281,410
	C_2H_4	Disordered	410
		c(2×2)–C	410
	benzene	Disordered	410

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ir(110)	C_2H_4	Disordered	347
		(1×1)–C	347
	benzene	Disordered	347
		(1×1)–C	347
Ir(111)	C_2H_2	$(\sqrt{3}\times\sqrt{3})R30°$	187
		(9×9)–C	187
	C_2H_4	$(\sqrt{3}\times\sqrt{3})R30°$	187
		(9×9)–C	187
	benzene	(3×3)	187
		(9×9)–C	187
	cyclohexane	Disordered	187
		(9×9)–C	187
Ir(S)–[6(111)×(100)]	C_2H_2	(2×2)	187
	C_2H_4	(2×2)	187
	benzene	Disordered	187
	cyclohexane	(2×2)	187
Mo(100)	CH_4	c(4×4)–C	286
		c(2×2)–C	286
		$c(6\sqrt{2}\times 2\sqrt{2})R45°$–C	286
		(1×1)–C	286
	C_2H_4	c(2×2)–carbide	602,603,659
		$\begin{pmatrix}3 & 0\\ 1 & -1\end{pmatrix}$	602,603,660
		(1×1)	602,603,660
		(1×1) w. Streaks	1379
		c(2×2)–C	660
	HCOOH	Disordered	1155
	O(a)+C_2H_4	(2×1)–O	817
	O(a)+HCOOH	(2×1)–O,C	1155
Ni(100)	CH_4	c(2×2)	117
		(2×2)	117
	C_2H_2	*c(2×2)	416,1923*
		(2×2)	416
		c(4×2)	417
		(2×2)–C	417
	C_2H_4	c(2×2)	88,416
		Quasi-c(2×2)	1561
		(2×2)	416
		*(2×2)–C(p4g)	417,670,745*, 1092,1177
		c(4×2)	417
		$(\sqrt{7}\times\sqrt{7})R19°$–C	88
	C_2H_6	c(2×2)	117
		(2×2)	117
	CH_3OH	Disordered	601
		c(2×2)	601
	benzene	c(4×4)	415
Ni(110)	CH_4	(2×2)	117
		(4×3)	117
		(4×5)–C	117,418
		(2×3)–C	418,679

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	C_2H_2	c(2×2)-C_2H_2	915
	C_2H_4	(2×1)-C	419,420,421
		(4×5)-C	419,420,915
		"c(2×4)"-C_2H_4	915
		c(2×2)-CCH	915
		Graphite Overlayer	420
	C_2H_6	(2×2)	117
	CH_3OH	c(2×4)-CH_3O	890
		c(2×6)-CH_3O	890
		c(2×2)-CO	890
	C_5H_{12}	(4×3)	422
		(4×5)	422
Ni(111)	CH_4	(2×2)	117
		(2×2)-C	990
		Graphite	990
		(2×$\sqrt{3}$)	117
		(16$\sqrt{3}$×16$\sqrt{3}$)-R30°-C	739
		(4×5)	739
	C_2H_2	*!(2×2)-C_2H_2	412,413,719,1262*,1925!
		($\sqrt{3}$×$\sqrt{3}$)R30°+(2×2)	719
		Disordered	1627
	C_2H_4	(2×2)	29,39,412
	C_2H_6	(2×2)	39,117
		(2×$\sqrt{3}$)	117
		($\sqrt{7}$×$\sqrt{7}$)R19°-C	29
		(2×2)-C	990
		Disordered Graphite	990
	benzene	(2$\sqrt{3}$×2$\sqrt{3}$)R30°	414,415
	cyclohexane	(2$\sqrt{3}$×2$\sqrt{3}$)R30°	414
Pb(100)	HCOOH	Not Adsorbed	1691
Pd(100)	benzene	c(4×4)	616,617
		(2×2)R45°-C_6H_6	616,617,630
Pd(111)	C_2H_2	($\sqrt{3}$×$\sqrt{3}$)R30°-C_2H_2	1043,1209
	C_2H_4	($\sqrt{3}$×$\sqrt{3}$)R30° Diffuse	1209
		Disordered	1266
		($\sqrt{3}$×$\sqrt{3}$)R30°-C_2H_3	1266
	CH_3OH	($\sqrt{3}$×$\sqrt{3}$)R30°-CO,H_2	1042
		Complex	1042
	Benzene	Disordered	961
	Benzene + CO	(2$\sqrt{3}$×2$\sqrt{3}$)R30°	961
		Complex	961
		*(3×3)-C_6H_6+2CO	961,1862*
Pt(100)	C_2H_2	c(2×2)	28,72,321,431,432
	C_2H_4	c(2×2)	28,72,313,321,431
		Graphite Overlayer	313,426
		(511),(311)facets	426
	acrylic acid	(1×1) Diffuse	1258
	acrylic acid(a)+NH_3	(1×1) Diffuse	1258
	aniline	Disordered	430
	benzene	Disordered	432
		2(1 dimensional order)	429
	cyanobenzene	Disordered	430
	mesitylene	3(1 dimensional order)	430

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	M-xylene	3(1 dimensional order)	430
	naphthalene	(1×1)	429
	nitrobenzene	Disordered	430
	N-butylbenzene	Disordered	430
	pyridine	(1×1)	429
		$c(2\times2)$	429
	toluene	3(1 dimensional order)	430
	T-butylbenzene	Disordered	430
Pt(110)	HCOOH	1–D Disordered	1080
	CH_3NCO	(1×2)	938
	benzene	Disordered	1172
Pt(111)	C_2H_2	(2×1)	28
		(2×2)	423,424,425,1316 1196
	$C_2H_2+H_2$	*(2×2)–C_2H_3	824*,1316,1587
	C_2H_4	(2×2)	40,424,425,1196 1313
		*(2×2)–C_2H_3	824*,1316,1586
		(2×1)	28
		2(1 dimensional order)–C	221
		Disordered	1316
		Complex	1313
		Graphite Overlayer	221,426,1093
	(O)+C_2H_4	(2×2)	1313
		Ordered	1313
	C_3H_4	(2×2)	1316
	$C_3H_4+H_2$	(2×2)	1316
	C_3H_6	Disordered	1316
		(2×2)	1316
	cis-2-C_4H_8	$(2\sqrt{3}\times2\sqrt{3})R30°$	1316
	trans-2-C_4H_8	(8×8)	1316
	$C_{10}H_8$	(6×3)–$C_{10}H_8$	668
	acetic acid	(2×2)	580,1287
		Disordered	587,1287
	acetnitrile	(1×1) Diffuse	1258
		(2×2)	580,1287
		Disordered	1287
	acetnitrile+I_2	I_2 Adsorbed	1258
	aniline	3(1 dimensional order)	430
	azulene	Disorderd	1349
		(3×3)	1349
		$(3\times3)+(3\times3)R30°$	1349
		(10×10)	1349
	benzene	Disordered	429,1854,1891
		*Graphite	1924*
	benzene+CO	$\begin{pmatrix}-2 & 2\\ 5 & 5\end{pmatrix} = \begin{pmatrix}4 & -2\\ 0 & 4\end{pmatrix}$	221,428,429
		*$\begin{pmatrix}4 & -2\\ 0 & 5\end{pmatrix} = \begin{pmatrix}-2 & 2\\ 4 & 4\end{pmatrix}$ $= (2\sqrt{3}\times4)$rect–$2C_6H_6+4CO$	428,429,1854*
	cyanobenzene	3(1 dimensional order)	430

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	cyclohexane	$\begin{pmatrix} 4 & -1 \\ 1 & 5 \end{pmatrix}$	427
		Disordered	221
		(2×2)	221
		Graphite Overlayer	221
	dichloromethane	Not Adsorbed	580
	dimethylsulfoxide	(2×2)	580,1287
		$(\sqrt{3}\times\sqrt{3})R30°$	1287
		(1×1)	1287
	dimethylformamide	(2×2) Diffuse	580,1258
		Disordered	1287
	DMSO	(1×1)–DMSO	1258
	DMSO(a)+I_2	Ordered	1258
	DMSO(a)+pyridine	Not Adsorbed	1258
	I(a)+pyridine	Not Adsorbed	1258
	I(a)+acetnitrile	Not Adsorbed	1258
	I(a)+DMSO	DMSO Not Adsorbed	1258
	I_2+DMSO	$c(2\times4\sqrt{3}/3)$–I,DMSO	1258
	mesitylene	3.4(1 dimensional order)	430
	m-xylene	2.6(1 dimensional order)	430
	naphthalene	(6×6)	224,429
		napthalene (001)	224
		(6×3)	1349
		Disordered	1349
	nitrobenzene	3(1 dimensional order)	430
	n-butane	$\begin{pmatrix} 2 & 1 \\ -1 & 2 \end{pmatrix}$	427
		$\begin{pmatrix} 2 & 2 \\ -5 & 5 \end{pmatrix}$	427
		$\begin{pmatrix} 3 & -2 \\ 2 & 5 \end{pmatrix}$	427
	N-butylbenzene	Disordered	430
	n-heptane	$\begin{pmatrix} 2 & 1 \\ 0 & 8 \end{pmatrix}$	427
		(2×2)	221
	n-hexane	$\begin{pmatrix} 2 & 1 \\ -1 & 3 \end{pmatrix}$	427
	n-octane	$\begin{pmatrix} 2 & 1 \\ -1 & 4 \end{pmatrix}$	427
	n-pentane	$\begin{pmatrix} 2 & 1 \\ 0 & 6 \end{pmatrix}$	427
	propylene-carbonate	(2×2)	580,1287
		Disordered	1287
	propanoic Acid	Disordered	587

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	pyridine	(2×2)	429,580,1287
		(1×1) Diffuse	1258
		Disordered	1287
	pyridine(a)+DMSO	Not Adsorbed	1258
	pyridine(a)+H_2O	Not Adsorbed	1258
	pyridine(a)+I_2	I_2 Adsorbed	1258
	p-dioxane	(2×2)	580,1287
		Disordered	1287
	sulfolane	(2×2)	580,1287
		$(\sqrt{3}\times\sqrt{3})R30°$	580,1287
		(1×1)	580,1287
	toluene	3(1 dimensional order)	221,430
		(4×2)	430
		Graphite Overlayer	430
	T-butylbenzene	Disordered	430
Pt(S)-[7(111)×(100)]	azulene	1/3 order ring	1057
	naphthalene	1/3 order spots	1057
Pt(S)-[4(111)×(100)]	C_2H_4	Disordered	221
		Graphite Overlayer	221
		Facets	221
	benzene	Disordered	221
		Graphite Overlayer	221
		Facets	221
	cyclohexane	Disordered	221
		(4×2)-C	221
	n-heptane	(4×2)	221
		(4×2)-C	221
	toluene	Disordered	221
		2(1 dimensional order)-C	221
Pt(S)-[6(111)×(100)]	C_2H_4	(2×2)	120,221
		$\begin{pmatrix} 3 & 2 \\ -2 & 5 \end{pmatrix}$-C	221
		$\begin{pmatrix} 6 & 1 \\ -1 & 7 \end{pmatrix}$-C	221
		$(\sqrt{19}\times\sqrt{19})R23.4°$-C	426
		Graphite Overlayer	426
	benzene	3(1 dimensional order)	221
		(9×9)-C	221
	cyclohexane	2(1 dimensional order)	221
	n-heptane	(2×2)	221
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	221
		(9×9)-C	221
	toluene	Disordered	221
		(9×9)-C	221
Pt(S)-[7(111)×(310)]	C_2H_4	Disordered	221
		Graphite Overlayer	221
	benzene	Disordered	221
	cyclohexane	Disordered	221
	n-heptane	Disordered	221

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	toluene	Disordered	221
		Graphite Overlayer	221
Pt(S)-[9(111)×(100)]	C_2H_4	Adsorbed	221
	benzene	Disordered	221
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$-C	221
		Graphite Overlayer	221
	cyclohexane	Disordered	221
	n-heptane	(2×2)	221
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$	221
		(5×5)-C	221
		(2×2)-C	221
		$\begin{pmatrix} 1 & 1 \\ -1 & 2 \end{pmatrix}$-C	221
		2(1 dimensional order)-C	221
	toluene	3(1 dimensional order)	221
		Graphite Overlayer	221
Pt(S)-[9(111)×(111)]	C_2H_4	Disordered	120
		Graphite Overlayer	398,399
		(2×2)	685
Pt(S)-[5(100)×(111)]	C_2H_4	Graphite Overlayer	426
		(511),(311) and (731) facets	426
Re(0001)	C_2H_2	Disordered	436,664
		$(2\times\sqrt{3})R30°$-C	436
	C_2H_4	Disordered	436,664
		$(2\times\sqrt{3})R30°$-C	436
Re(S)-[14(0001)×(10$\bar{1}$1)]	C_2H_2	Disordered	664
	C_2H_4	$(2\times\sqrt{3})R30°$	664
Re(S)-[6(0001)×(16$\bar{7}$1)]	C_2H_2	Disordered	664
	C_2H_4	Disordered	664
Rh(100)	C_2H_2	c(2×2)	231
		c(2×2)-C_2H+C_2H_3	1880
	C_2H_4	c(2×2)	231
		c(2×2)-C_2H+C_2H_3	1878
		(2×2)-C_2H	1878
		c(2×2)-C	231,1403
		Graphite Overlayer	231,1403
	CO+C_2H_4	c(4×2)-CO+C_2H_3	1878
		split c(2×2)-CO+C_2H_3	1878
	C_6H_6	c(4×4)	1879
	C_6H_6+CO	$c(2\sqrt{2}\times4\sqrt{2})R45°$-CO+$C_6H_6$	1879
		c(2×2)	1879

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Rh(111)	C_2H_2	c(4×2)	231,831
		(2×2)	831
	C_2H_2+CO	c(4×2)–CO+C_2H_2	1844,1881
	C_2H_2+Na	Disordered	1876
	C_2H_4	c(4×2)	231,831,1256,1372
		*(2×2)–C_2H_3(ethylidyne)	831,1256*,1372
		Partially Ordered	955
		(8×8)–C	231
		(2×2)R30°–C	231
		($\sqrt{19}\times\sqrt{19}$)R23.4°–C	231
		($2\sqrt{3}\times2\sqrt{3}$)R30°–C	231
		(12×12)–C	231
	C_2H_4+CO	c(4×2)–CO+C_2H_3	1881
	C_2H_4+NO	*c(4×2)–NO+C_2H_3	1877*
	C_2H_4+H_2	c(4×2)–CCH_3	955
		c(4×2)	1372
		(2×2)+c(4×2)	1256
	C_3H_6+CO	($2\sqrt{3}\times2\sqrt{3}$)R30°–CO+C_3H_5	1884
	CH_3OH	Disordered	988
	benzene	($2\sqrt{3}\times3$)rect	1842,1892
		($\sqrt{7}\times\sqrt{7}$)R19.1°	1892
	benzene+CO	*c($2\sqrt{3}\times4$)rect	1068,1416,1453,1842,1856*,1892
		$=\begin{pmatrix}3 & 1\\ 1 & 3\end{pmatrix}$–$C_6H_6$+CO	
		*(3×3)–C_6H_6+2CO	1068,1842,1855*,1892
	benzene+Na	($\sqrt{3}\times\sqrt{3}$)R30°+($2\sqrt{3}\times3$)rect	1876
	C_6H_5F+CO	(3×3)	1844
	methylacetylene	c(4×2)	1372
	naphthalene	($3\sqrt{3}\times3\sqrt{3}$)R30°	1068
		(3×3)	1068
	propylene	(2×2)+($2\sqrt{3}\times2\sqrt{3}$)R30°	1372
		($2\sqrt{3}\times2\sqrt{3}$)R30°	1372
Rh(331)	C_2H_2	$\begin{pmatrix}-1 & 1\\ 3 & 0\end{pmatrix}$	402
	C_2H_4	$\begin{pmatrix}-1 & 1\\ 3 & 0\end{pmatrix}$	402,722
		Graphite Overlayer	402,722
Rh(S)–[6(111)×(100)]	C_2H_2	Disordered	402
	C_2H_4	Disordered	402,722
		(111),(100) facets	402,722

TABLE VII. Surface Structure Formed by Adsorption of Organic Molecules (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ru(0001)	C_2H_6	Disordered	692
	cycropropane	Disordered	692,1111
	cyclohexane	Disordered	692,1112
		(1×1)	692
	cyclooctane	(1×1)	692
Si(111)	C_2H_2	Disorderd	437
	CH_3OH	(7×7)–CH_3O+H+CH_3OH	837
		Disordered	988
		Disorderd CH_3O+H	942
Si(311)	C_2H_2	c(1×1)	135
		(2×1)	135
		(3×1)	135
	C_2H_4	c(1×1)	135
		(2×1)	135
		(3×1)	135
Ta(100)	C_2H_4	Adsorbed	328
W(100)	CH_4	(5×1)–C	41
	C_2H_2	Disordered	700
		(5×1)–C	700,901
		c(3×2)–C	700
		c(2×2)–C	700
	propylene	$\begin{pmatrix} 3 & 0 \\ 1 & -1 \end{pmatrix}$–C	887
		(5×1)–C	887
W(110)	C_2H_2	(2×2)–C_2H_2	1072
		c(2×2)–C_2H_2	1072
		(15×3)R14°–C	1072
	C_2H_4	(15×3)Rα–C	41
		(15×12)Rα–C	41
W(111)	CH_4	(6×6)–C	41
	C_2H_4	(1×1)	1595
	C_2H_6	(1×1)	1595
W(211)	propylene	c(6×4)–C	887
ZnO(10$\bar{1}$0)	C_6H_6	c(2×2)–C_6H_6	632,620
		c(4×3)–C_6H_6	632,620

TABLE VIII. Coadsorbed Overlayer Structures

Substrate	Adsorbate	Surface Structure	Reference
Ag(100)	Cl_2+K	c(2×2)–K/Cl	673
	K+O_2	$\begin{pmatrix} 1 & 1 \\ -5 & 4 \end{pmatrix}$	658
		Hexagonal Overlayer	658
	O(ad.)+H_2O	c(2×2)–OH	1034
Ag(110)	C_2H_4+O_2	(2×1)–O	1001
	H_2O+Li^+	Complex	1557
	O(a)+C_2H_2	c(2×6)–acetylide	1335,1398
		(2×2)–acetylide	1335,1398
		(2×3)–acetylide	1335,1398
		(1×1)–C	1335
	O(a)+SO_2	c(6×2)–SO_3	1027,1371
		(1×2)–SO_4	1371
	O_2+H_2O	(1×2)–OH	878
		(1×3)–OH	878
Ag(111)	CO+O_2	(2×$\sqrt{3}$)–(CO+O_2)	27
Bi(0001)	O_2+K	$\sqrt{3}$+BiO(0001)layer	1288
C(0001), graphite	Ar+Xe	($\sqrt{3}$×$\sqrt{3}$)R30°–Ar,Xe	1193
Co(100)	H_2S+C	(2×2)–S,C	1539
Cr(100)	C,O,N	c(2×2)	1126
Cu(110)	Br(a)+H_2O	(3×2)	1557
	C+O_2	(2×1)	1695
	Ni(CO_4)+CO	(1×1)	1048
	O(a)+CO	Disordered	1066
	O(a)+H_2O	(2×1)–O,H_2O	1023
		c(2×2)–O,H_2O	1023
		(2×1)–H_2O	1270
		(1×1)–H_2O,OH	1270
		(2×1)–OH,O	1270
Cu(111)	$Ni(CO)_4$+CO	(1×1)	1048
	O_2+HCN	Disordered	1244
	O(a)+CO	Disordered	1066
	O(a)+CO_2	(2×2)	1142
Fe(110)	K+O_2	c(4×2)	786
Fe(111)	N(a)+K	(3×3)–K,N	1350
Fe–18% Cr–12% Ni(111)	I(a)+H_2O	Oxide Not Formed	1249
	H_2O(a)+I_2	Adsorbed	1249
GaAs(100)	As_4,Ga	(2×4)	1365
		(4×6)	1365
		c(8×2)	1365
		(4×1)	1365
		(3×1)	1365
	HCl,H_2O	(1×1)	1518
	Pb,As_4	(1×2)–Pb	1387
Hg(110)	O(ad)+SO_2	c(6×2)–SO_3	1027,1371
		(1×2)–SO_4 etc.	1371
	O_2+H_2O	(1×2)–OH	878
		(1×3)–OH	878
Mo(100)	Cs+O_2	c(2×2)+(4×1)	932
		(4×1)	932
		c(2×2)	932

TABLE VIII. Coadsorbed Overlayer Structures (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	H_2S+O_2	$(\sqrt{5}\times\sqrt{5})R26.6°$–S,O	917
	O(a)+CO	(2×1)–O	817
	$O(a)+CO_2$	(2×1)–O	817
	$O(a)+C_2H_4$	(2×1)–O	817
	O(a)+HCOOH	(2×1)–O,C	1155
Mo(111)	N_2+NH_3	Disordered	1203
	N_2+NH_3	(433)facet	1203
		c(3×2)–N/Mo(433)	1203
Ni(100)	$C(a)+O_2$	c(2×2)–O	1177
	$CO+H_2$	c(3×3)	301
	H_2+CO	c(2×2)–CO,H	1202
		$c(\sqrt{2}\times2\sqrt{2})R45°$–CO,H	1202
	H_2S,H_2	c(2×2)–S	1121
	H_2S+Na	*c(2×2)Na+c(2×2)S	1887*
		*(2×2)Na+c(2×2)S	1887*
		*(2×2)Na+(2×2)S	1887*
	O(a)+CO	c(2×2)–C,O	1356
	S,C	(1×1)	1561
Ni(110)	$CO+O_2$	$(3\times1)–(CO+O_2)$	91
	O_2+H_2O	(2×1)–OH	1011
Ni(111)	$NI(CO)_4$,CO	$(\sqrt{7}/2\times\sqrt{7}/2)R19°$–CO	1150
		c(4×2)–CO	1150
Ni(111)	$O(a)+H_2O$	No New Features	1308
	O(a)+NO	(2×2)	676
Ni(331)	O,CO	(2×3)	1318
Pd(100)	$H(a)+O_2$	Adsorbed	1163,1454
	H_2,O_2	Disordered	1163
		(2×2)–O,H	1163
	O_2+CO	Disorderd	939
	O_2+H_2O	(2×1)–OH	940
	$O(a)+H_2$	Not Adsorbed	1163,1454
Pd(111)	O_2+CO	$(\sqrt{3}\times\sqrt{3})R30°$	691
		(2×1)	691
Pt(100)	$CO+H_2$	$c(2\times2)–(CO+H_2)$	72,74
	$CO+O_2$	(1×1) diffuse	909
		c(2×2)–CO+(3×1)–O	928
	H_2O+HBr	$c(2\sqrt{2}\times\sqrt{2})R45°$–Br,HBr	1258
	$Br,HBr(a)+H_2O$	Not Adsorbed	1258
	$Br,HBr(a)+NH_3$	No Affinity	1258
	I(a)+Ag	$(\sqrt{2}\times\sqrt{2})R45°$–I,Ag	1390
		$(10\sqrt{2}\times10\sqrt{2})R45°$–I,Ag	1390
		$(\sqrt{34}\times\sqrt{34})R31°$–I,Ag	1390
	$SO_2(a)+NH_3$	(1×1) Diffuse	1258
Pt(110)	CO+NO	(1×1)–CO+NO	364

TABLE VIII. Coadsorbed Overlayer Structures (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Pt(111)	$C_2H_2+H_2$	*(2×2)–C_2H_3	824,1316,1587
	(O)+C_2H_4	(2×2)	1313
		Ordered	1313
	benzene+CO	$\begin{pmatrix} -2 & 2 \\ 5 & 5 \end{pmatrix} = \begin{pmatrix} 4 & -2 \\ 0 & 4 \end{pmatrix}$	221,428,429
		* $\begin{pmatrix} 4 & -2 \\ 0 & 5 \end{pmatrix} = \begin{pmatrix} -2 & 2 \\ 4 & 4 \end{pmatrix}$	428,429,1854*
		= $(2\sqrt{3}\times4)$rect-2C_6H_6+4CO	
	DMSO(a)+I_2	Ordered	1258
	DMSO(a)+pyridine	Not Adsorbed	1258
	I(a)+pyridine	Not Adsorbed	1258
		Pyridine Adsorbed	1258
	I(a)+acetnitrile	Acetnitrile Not Adsorbed	1258
	I(a)+DMSO	DMSO Not Adsorbed	1258
	I_2+DMSO	c$(2\times4\sqrt{3}/3)$–I,DMSO	1258
	pyridine(a)+DMSO	Adsorbed	1258
	pyridine(a)+H_2O	Adsorbed	1258
	pyridine(a)+I_2	I_2 Adsorbed	1258
	$H_2+C_2N_2$	Disorderd	1002
	Cl_2+Br_2	c(2×4)–Cl,Br	610
		$(\sqrt{3}\times\sqrt{3})$R30°–Cl,Br	610
		(3×3)–Cl,Br	610
		$(\sqrt{7}\times\sqrt{7})$R19.1°	610
	CO+O_2	$(\sqrt{3}\times\sqrt{3})$R30°(misfit)	909
	H_2+O_2	$(\sqrt{3}\times\sqrt{3})$R30°	11
	I_2(a)+HBr	HBr Not Adsorbed	1258
	I(a)+Cu	(3×3)–I,Cu	1556
		(10×10)–I,Cu	1556
	I_2+Ag	(3×3)–Ag,I	937,1106,1391
		(5×5)–Ag,I	937
		(17×17)–Ag,I	937
		$(\sqrt{7}\times\sqrt{7})$+(3×3)	1391
		$(\sqrt{3}\times\sqrt{3})$R30°–Ag,I	1391
	K+CO	Disorderd	1255
	K+O_2	(4×4)–K,O	1238,1337
		(8×2)	1337
		(10×2)	1337
		K_2O	1337
	S+O_2	(2×2)–O	1040
Pt(S)–[6(111)×(100)]	K(a)+O_2	(4×4) Potassium Oxide	1337
		(8×2) Potassium Oxide	1337
		(10×2) Potassium Oxide	1337
Rh(100)	CO(a)+D_2	Compressed (CO)	1348
	CO+CH_4	c(4×2)–CO+C_2H_3	1878
		split c(2×2)–CO+C_2H_3	1878
	C_6H_6+CO	c$(2\sqrt{2}\times4\sqrt{2})$R45°–CO+$C_6H_6$	1879
	D(a)+CO	c(2×2)	1348
	NO+D_2	Disordered	1025
	Na+H_2O	$(2\sqrt{3}\times\sqrt{3})$R30	1082
		Complex	1082

TABLE VIII. Coadsorbed Overlayer Structures (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Rh(111)		$(\sqrt{3}\times 7)$rect	1844
	CO+Na	c(4×2)–CO+Na	1844
	H_2+CO	(2×2)	829
		$(\sqrt{3}\times\sqrt{3})$R30°	829
	$C_2H_2+H_2$	c(4×2)	231,831
	C_2H_2+CO	c(4×2)–CO+C_2H_2	1844,1881
	C_2H_2+Na	Disordered	1876
	$C_2H_4+H_2$	c(4×2)–CCH_3	955
		c(4×2)	1372
		(2×2)+c(4×2)	1256
	C_3H_6+CO	$(2\sqrt{3}\times 2\sqrt{3})$R30°–CO+$C_3H_5$	1884
	Benzene+CO	*c$(2\sqrt{3}\times 4)$rect	1068,1416,1453,1842,1856*
		$= \begin{pmatrix} 3 & 1 \\ 1 & 3 \end{pmatrix}$–$C_6H_6$+CO	
		*(3×3)–C_6H_6+2CO	1068,1842,1855*
	Benzene+Na	$(\sqrt{3}\times\sqrt{3})$R30°+$(2\sqrt{3}\times 3)$rect	1876
	C_6H_5F+CO	(3×3)	1844
	NO+CO	Disordered	1876
Ru(0001)	CO+O_2	(2×2)	768
	Na+CO	$(2\sqrt{3}\times 2\sqrt{3})$R30°	976
Si(111)	Ag(a)+H	$(\sqrt{3}\times\sqrt{3})$R30°	1536
W(100)	CO+N_2	(4×1)–(CO+N_2)	82
	O_2+H_2	$(\sqrt{2}\times\sqrt{2})$+(4×1)–O,H	815
W(110)	CO+O_2	c(11×5)–(CO+O_2)	93
	Pd(1 ML)+CO	Not Adsorbed	1218
	Pd(2.2 ML)+O_2	(2×2)–O	1218
W(221)	CO+O_2	(1×1)–(CO+O_2)	108
		(1×2)–(CO+O_2)	108

TABLE IX. Physisorbed Overlayer Structures

Substrate	Adsorbate	Surface Structure	Reference
Ag(110)	Xe	Hexagonal Overlayer	159
Ag(111)	Kr	Hexagonal Overlayer	156
	Xe	Hexagonal Overlayer	156,157,158,159 160
Ag(211)	Xe	Hexagonal Overlayer	159
Au(100)	Xe	Disordered	252
C(0001), graphite	Ar	$(\sqrt{3}\times\sqrt{3})R30°-Ar$	720,960
	Ar	Incommensurate	1882
	Ar+Xe	$(\sqrt{3}\times\sqrt{3})R30°-Ar,Xe$	1193
	CF_4	$(2\times2)-CF_4$	1194
		Close to (2×2)	1404
	CH_4	$(\sqrt{3}\times\sqrt{3})R30°$	1018
	C_2H_6	$(4\times\sqrt{3})-C_2H_6$	1191
		$(2\times2)-C_2H_6$	1191
		$(10\times2\sqrt{3})-C_2H_6$	1191
		$(\sqrt{3}\times\sqrt{3})-C_2H_6$	1191
	CO	$(\sqrt{3}\times\sqrt{3})R30°-CO$	884
		$(2\sqrt{3}\times2\sqrt{3})R30°-CO$	889
		$(2\sqrt{3}\times\sqrt{3})R30°$	884
		Incommensurate(2×2)	884
	H_2	$(\sqrt{3}\times\sqrt{3})R30°-H_2$	1283
	Kr	$(\sqrt{3}\times\sqrt{3})R30°-Kr$	166,167,174,721 828,960,1616
		Incommensurate	1616
	N_2	$(2\sqrt{3}\times2\sqrt{3})R30°-N_2$	889
		$(\sqrt{3}\times\sqrt{3})R30°$	1064
		$(\sqrt{3}\times\sqrt{3})R30°+(2\times1)$	1435
		Commensurate	1190,1512,1883
		Incommensurate	1443,1190,1512,1883
	Ne	Incommensurate	629
		$(\sqrt{3}\times\sqrt{3})R30°$ rotated by 17°	629
		Layer+Island	960
		Ordered	1338
	NO	Incommensurate	1602
	O_2	Triangular	1883
		Centered-Parallelogram$-O_2$	1200,1425,1883
		Physisorbed	1411
	Xe	$(\sqrt{3}\times\sqrt{3})R30°-Xe$	165,618,960,1038,1201
Cu(100)	Xe	Hexagonal Overlayer	159
		Disordered	741
Cu(110)	Kr	$c(2\times8)-Kr$	1304,1331
	Xe	$c(2\times2)-Xe$	159,1331,1611
		Hexagonal Overlayer	159,1611
Cu(111)	Xe	$(\sqrt{3}\times\sqrt{3})R30°-Xe$	159
Cu(211)	Kr	Hexagonal Overlayer	156
	Xe	Hexagonal Overlayer	156
Cu(311)	Xe	Hexagonal Overlayer	394
Cu(610)	Xe	$(2\times6)-Xe$	790
Ir(100)	Kr	$(3\times5)-Kr$	283
		Kr(111)	283
NaCl(100)	Xe	Hexagonal Overlayer	289
Ni(100)	Xe	Partially Ordered	1268

TABLE IX. Physisorbed Overlayer Structures (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Pd(100)	Kr	Liquid-like	913
	Xe	Hexagonal Overlayer	311
		Liquid-like	913
Pd(110)	Xe	Hexagonal	743
Pd(S)-[8(100)×(110)]	Xe	1-D Periodicity	1100
Pt(111)	Xe	$(\sqrt{3}\times\sqrt{3})R30°$-Xe	846
		Hexagonal Overlayer	846
Si(111)	Kr	(1×1)	1125
	Xe	(1×1)	1125
W(110)	Xe	(2×2)-Xe	713
		Disordered	713
ZnO(000$\bar{1}$)	Xe	Disordered	1026
ZnO(10$\bar{1}$0)	Xe	Hexagonal	1026

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates[†]

Substrate	Adsorbate	Surface Structure	Reference
Ag(211)	Xe	Hexagonal Overlayer	159
Ag(331)	Cl_2	(6×1)–Cl	393
	O_2	Disordered	393
		Ag(110)–(2×1)–O	393
Al(311)	[clean]	*(1×1)	860*
Au(210)	Pb	(1×1)	497
Au(311)	Pb	(5×3)	496
		(3×3)–Pb	730
		(3×4)–Pb	730
Au(320)	Pb	(3×3)	496
		(1×1)	730
Au(511)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ 1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(711)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(911)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
	Pd	c(2×2)	683
		$c(7\sqrt{2}\times\sqrt{2})R45°$	683
		$c(3\sqrt{2}\times\sqrt{2})R45°$	683
		c(6×2)	683
Au(11,1,1)	Pb	$\begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$	444
		$\begin{pmatrix} 2 & 0 \\ -1 & 3 \end{pmatrix}$	444
Au(S)–[6(111)×(100)]	O_2	Oxide	161
Bi$(1,0,\bar{1},16)$	[clean]	(1×1)	1109

[†]Organic overlayer structures are not included. See Table VII for these structures.

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
C(0001) [stepped]	K	(1×1)–K	1433
	K	(2×2)–K	1433
	K	No LEED Superstructure	1540
Co(10$\bar{1}$2)	[clean]	(1×1)	698,1584
	CO	Co_3C(001)–(2×3)	698
		(3×1)–CO	698
Cu(210)	O_2	(410),(530)facets	259
		Streak pattern	688
		(2×1)–O	688
		(3×1)–O	688
	N	c(11$\sqrt{2}$×$\sqrt{2}$)R45°–N	794
		(2×3)–N	794
Cu(211)	Kr	Hexagonal Overlayer	156
	O_2	Cu(S)[5(111)×2(100)]	958
	Facet		958
	Pb	(4×1)	484
	Xe	Hexagonal Overlayer	156
Cu(311)	[clean]	*(1×1)	925,1473,1782*
	CO	Adsorbed	394
	Pb	$\begin{pmatrix} 3 & 1 \\ -2 & 1 \end{pmatrix}$	484
		(4×2)	484
	Xe	Hexagonal Overlayer	394
Cu(322)	O_2	(1×1)–O	1257
Cu(410)	O_2	(1×1) Streaked	958
		!(1×1)–O ["c(2×2)–O" on a terrace]	958!,1133,1257
		!(1×1)–2O	958!
Cu(511)	[clean]	(1×1)	925
	Pb	(4×1)	482
Cu(530)	O_2	(1×1)–O	1257
Cu(610)	Xe	(2×6)–Xe	790
Cu(711)	[clean]	(1×1)	925
	Pb	(4×1)	482,484
Cu(841)	O_2	(410),(100)facets	259
Cu(S)–[3(100)×(100)]	CO	Not Adsorbed	132
	N_2	(1×2)–N	132
Cu(S)–[4(100)×(100)]	CO	Not Adsorbed	132
	N_2	(1×3)–N	132
	O_2	(1×1)–O	132
Cu(S)–[4(100)×(111)]	H_2S	8(1d)–S	35
Fe(210)	[clean]	*(1×1)	1530,1767*
Fe(211)	[clean]	*(1×1)	1460*,1531
Fe(310)	[clean]	*(1×1)	1410*,1530
Fe(12,1,0)	N_2	Reconstruction by Nitride Formation	669
GaAs(211)	[clean]	(110)facets	936
Ge(210)	[clean]	(2×2)	804,1683
Ge(211)	[clean]	(3×1) (311)facets	936
		(1×2)	804,1683
Ge(311)	[clean]	(3×1)	804,1683
Ge(331)	[clean]	(5×1)	804,1683
Ge(510)	[clean]	(1×2)	804,1683

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Ge(511)	[clean]	(3×1)	804,1683
Ge(551)	[clean]	(5×2)	804,1683
Ir(S)-[6(111)×(100)]	CO	Disordered	182
	H_2	Adsorbed	187
	H_2O	Not Adsorbed	182
	O_2	(2×1)-O	182
$LaB_6(210)$	O_2	Disordered	1624
Mo(100)[Stepped]	Cs	(2×2)	932
		c(2×2)	932
	$Cs(a)+O_2$	c(2×2)	932
		Disordered	932
Mo(211)	Ba	(1×5)	1591,1675
		(4×2)	1591
	Cs	c(2×1/J),0.15<J<0.64	1590
		c(2×2)	1590
	CO	Disordered	105
	H_2	(1×2)-H	105
	La	Linear Chains	1447
		c(2×2)	1447
		c(2×4/3)	1447
	Li	(1×4)-Li	1593
		(1×2)-Li	1593
		(1×1)-Li	1593
	N_2	Not Adsorbed	105
	Na	(1×4)-Na	1684
		(1×3)-Na	1684
		(1×2)-Na	1684
		(1×3/2)-Na	1684
	O_2	(2×1)-O	105
		(1×2)-O	105
		(1×3)-O	105
		c(4×2)-O	105
	Sr	(1×9)-Sr	1594
		(1×5)-Sr	1594
		(4×2)-Sr	1594
Nb(750)	O_2	(110)Terrace+(310)Step	1688
Ni(210)	N_2	Ni(100)-(6$\sqrt{2}$×$\sqrt{2}$)R45°-N	395
		c(11$\sqrt{2}$×$\sqrt{2}$)R45°-N	794
		(2×3)-N	794
		Ni(110)-(2×3)-N	395
	O_2	Facets	395,794
Ni(211)	O_2	NiO	1351
Ni(311)	[clean]	*(1×1)	900*,1473, 1885*,1886*
Ni(331)	[clean]	(1×1)	1247,1893
	S	(1×2)-S	1893
		(2×5)-S	1893
		(2×1)-S	1893
	O,CO	(2×3)	1893
Ni(hk0)[(210)to(410)]	[clean]	Ordered	871
	O_2	Facets	871
Ni(S)-[3(100)×(111)]	H_2S	(2×2)	1055
Ni(S)-[5(100)×(111)]	[clean]	Streaks	1055
	CO	Streaks Disappear	1055

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
	H_2S	Streaks Disappear	1055
$Ni_4Mo(211)$	[clean]	Ordered	1115
Pd(111)[Stepped]	NO	c(4×2)–NO	1236
		(2×2)–NO	1236
Pd(210)	CO	(1×1)–CO	209,210
		(1×2)–CO	209,210
Pd(311)	CO	(2×1)–CO	209
		3(1 dimensional order)–CO	209
Pd(331)	O_2	Disordered	675
		2(1 dimensional order)	675
		$\begin{pmatrix} 1 & 2 \\ 2 & 0 \end{pmatrix}$–O	675
	NO	Disordered	675
Pd(S)–[8(100)×(110)]	Xe	1–D Periodicity	1100
Pd(S)–[9(111)×(111)]	CO	$(\sqrt{3}\times\sqrt{3})R30°$–CO	209
		Hexagonal Overlayer	209
Pt(321)	[clean]	Ordered	1212
	O_2	Disordered	760
Pt(654)	O_2	$(\sqrt{3}\times\sqrt{3})R30°$–O	760
Pt(997)	[clean]	(1×1)	1226,1278
	O_2	Pt(S)–[(17(111)×2(11$\bar{1}$)]–O	1226,1278
Pt(12,9,8)	O_2	$(\sqrt{3}\times\sqrt{3})R30°$–O	760
Pt(12,11,9)	[clean]	(1×1)	1226
Pt(62,62,60)	[clean]	(1×1)	1226
		(2×2)–O	760
Pt(S)–[4(111)×(100)]	CO	Disordered	899
	H_2	Facets	221
Pt(S)–[5(100)×(111)]	O_2	(1×1)–O	708,1171
		$(2\sqrt{2}\times\sqrt{2})R45°$–O	708,1171
		Terrace Broadening and Diffused Background	1171
Pt(S)–[6(111)×(111)]	I_2	(3×3)or$(\sqrt{3}\times\sqrt{3})R30°$ Domains	930
	NH_3	Adsorbed	626
	O_2	$(\sqrt{3}\times\sqrt{3})R30°$–$PtO_2(0001)$	805
		$(4\sqrt{3}\times2\sqrt{3})R30°$–$PtO_2(0001)$	805
Pt(S)–[6(111)×(100)]	CO	Disordered	120
	H_2	2(1 dimensional order)–H	120,221
		Adsorbed	396
		Pt(S)–[11(111)×2(100)]	396
	K(a)+O_2	(4×4) Potassium Oxide	1337
		(8×2) Potassium Oxide	1337
		(10×2) Potassium Oxide	1337
	O_2	2(1 dimensional order)–O	120
		Pt(111)–(2×2)–O	215,708,1171
		Pt(111)–$(\sqrt{3}\times\sqrt{3})R30°$–O	215
		Pt(111)–$(\sqrt{79}\times\sqrt{79})$–R18°7′–O	215
		Pt(111)–$(4\times2\sqrt{3})$–R30°–O	215
		Pt(111)–3(1 dimensional order)–O	215
		Reconstructed (2×2) Terrace Broadening	1171

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
Pt(S)-[7(111)×(310)]	O_2	$(\sqrt{3}\times\sqrt{3})$-R30°-O	760
		(2×2)-O	760
Pt(S)-[9(111)×(100)]	H_2	2(1 dimensional order)-H	221
	H_2S	(2×2)-S	1339
		$(\sqrt{3}\times\sqrt{3})$-R30°-S	1339
Pt(S)-[9(111)×(111)]	C_2N_2	Disordered	685
	CO	Disordered	120,685
		$(\sqrt{3}\times\sqrt{3})$R30°-CO	685
		c(4×2)-CO	685
	H_2	(2×2)-H	120
		Adsorbed	400
	N	Disordered	228
	O_2	(2×2)-O	397,398,399,685
		Not Adsorbed	120
Pt(S)-[12(111)×(111)]	NH_3	Disordered	401
	NO	(2×2)-NO	401
	O_2	(2×2)-O	689
Pt(S)-[13(111)×(310)]	O_2	(2×2)-O	708,1171
		$(\sqrt{3}\times\sqrt{3})$R30°-O	708
		Reconstructed (2×2) Terrace Broadening	1171
Pt(S)-[20(111)×(111)]	O_2	(2×2)-O	1013
Re(S)-[6(0001)×(16$\bar{7}$6)]	O_2	ReO_3 Reconstruction	1654
Re(S)-[14(0001)×(10$\bar{1}$1)]	CO	(2×2)-CO	230
		(2×1)-C	230
	H_2	Disordered	663
Re(S)-[(14(0001)×(16$\bar{7}$1)]	H_2	Disordered	664
Re(S)[16(0001)×2(10$\bar{1}$1)]	O_2	(2×2)	1515
Rh(331)	[clean]	(1×1)	839
	CO	$\begin{pmatrix} 1 & 2 \\ 5 & -1 \end{pmatrix}$-CO	402,722
		$\begin{pmatrix} 1 & 2 \\ 2 & 0 \end{pmatrix}$-CO	402
		Hexagonal Overlayer	402
	CO_2	$\begin{pmatrix} 1 & 2 \\ 5 & -1 \end{pmatrix}$-CO	402
		$\begin{pmatrix} 1 & 2 \\ 2 & 0 \end{pmatrix}$-CO	402,722
		Hexagonal Overlayer	402,722
	H_2	Adsorbed	402
		(1×1)	722
	NO	Disordered	402
		$\begin{pmatrix} -1 & 1 \\ 3 & 0 \end{pmatrix}$	402
	O_2	2(1 dimensional order)-O	402,722

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
		$\begin{pmatrix}1 & 2\\2 & 0\end{pmatrix}$-O	402,722
		$\begin{pmatrix}1 & 2\\7 & -1\end{pmatrix}$-O	402,722
		Facets	402
Rh(S)-[6(111)×(100)]	CO	($\sqrt{3}\times\sqrt{3}$)-R30°-CO	402,722
		(2×2)-CO	402
	CO_2	($\sqrt{3}\times\sqrt{3}$)-R30°-CO	402
		(2×2)-CO	402,722
	H_2	Adsorbed	402
		(1×1)	722
	NO	(2×2)-NO	402,722
	O_2	(2×2)-O	402,722
		Rh(S)-[12(111)×2(100)]-(2×2)-O	402
		Rh(111)-(2×2)-O	402
Si(111)[Stepped]	Ni	Si(221)-(2×2)	964
	Pd	Si(221)-(2×2)	964
	Si+laser	Unchanged	1392
Si(210)	[clean]	(2×2)	803,1685
Si(211)	[clean]	Complex	1317
		(4×2)	803,936,1685
	Ga	Ordered	1317
	H_2	Ordered (facet)	1317
Si(311)	[clean]	(3×2)	803,1685
	NH_3	Adsorbed	238
Si(320)	[clean]	(1×2)	803,1685
		(1×1)	803
		Facet	803
Si(331)	[clean]	(13×1)	803
		(13×2)	1685
Si(510)	[clean]	(1×2)	803,1685
Si(511)	[clean]	(3×1)	803,1685
Si(S)-[14(111)×($\overline{112}$)]	Si	(1×1)	1517
Si(hkl)([001]zone)	[clean]	Facets	892
	Au	Diffuse	892
		Facets	892
		3d-Au clusters	892
Ta(211)	CO	Disordered	101,102
		(3×1)-O	102
	H_2	(1×1)-H	102
	N_2	Disordered	102
		(311) facets	102
	O_2	(3×1)-O	101,102
Ti_2O_3 (047)	[clean]	(1×1)	1020
		Oxide	101,102
W(100)[Stepped]	[clean]	($\sqrt{2}\times\sqrt{2}$)R45°	1243
W(210)	CO	(2×1)-CO	138,575,1647
		(1×1)-CO	138
	N_2	(2×1)-N	131,575,887,1647

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
W(211)	[clean]	(1×1)	887
		(1×2)	1147
	Ag	(1×1)-Ag	969
	Au	(1×1)	969
		(1×2)	969
		(1×3)	969
		(1×4)	969
	C	c(10×4)-C	887
		c(6×4)-C	887
	CO	c(2×4)-C,O	887
	H_2S	c(2×6)-S	887
		c(2×2)-S	887
	Li	(4×1)	518,520
		(3×1)	518,520
		(2×1)	518,520
		Incoherent	518,520
		(1×1)	518,520
		[clean]	(2×2)
	Mg	(1×7)-Mg	1657
		(3×3)-Mg	1657
	Na	(2×1)	521
		Compressed(2×1)	521
	O_2	(2×1)-O	15,106,107,108,403, 404,887,1415,1431
		(1×1)-O	106,107,403,404,887
		(1×2)-O	15,106,404,887
		(1×3)-O	106
		(1×4)-O	106,404
		(1×n)-O (n=3–7)	887
	Sb	(2×1)	553
		(1×1)	553
W(221)	CO	Disordered	108
		c(6×4)-CO	108
		(2×1)-CO	108
		c(2×4)-CO	108
	$CO+O_2$	(1×1)-$CO+O_2$	108
		(1×2)-$CO+O_2$	108
	H_2	(1×1)-H	112
	Na	Compressed(2×1)	521
		(2×1)	521
	Ni	(1×1)-Ni	970
		(6×1)-Ni	970
	NH_3	c(4×2)-NH_2	113
	O_2	(2×1)-O	15,106,107,108 403,404
		(1×2)-O	15,106,404
		(1×1)-O	106,107,403,404
		(1×3)-k	106
		(1×4)-O	106,404
W(310)	N_2	(2×1)-N	131
		c(2×2)-N	131
	O_2	(2×1)-O	1389

TABLE X. Surface Structures on High-Miller-Index (Stepped) Substrates (Continued)

Substrate	Adsorbate	Surface Structure	Reference
W(S)-[6(110)×(1$\bar{1}$0)]	O_2	(2×1)-O	382
W(S)-[8(110)×(112)]	O_2	(2×1)-O	382
W(S)-[10(110)×(011)]	O_2	(2×1)-O	405
W(S)-[12(110)×(1$\bar{1}$0)]	O_2	(2×1)-O	382
W(S)-[13(001)×(1$\bar{1}$0)]	H_2	($\sqrt{2}\times\sqrt{2}$)R45°-H	945
		Incommensurate	945
		(1×1)-H	945
W(S)-[16(110)×(112)]	O_2	(2×1)-O	382
W(S)-[24(110)×(011)]	O_2	(2×1)-O	405
ZnO(40$\bar{4}$1)	[clean]	Similar to 1×1	1239
ZnO(50$\bar{5}$1)	[clean]	Similar to 1×1	1239

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LAWRENCE BERKELEY LABORATORY
TECHNICAL INFORMATION DEPARTMENT
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720