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Applications of TEM to Interfaces in Materials



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U. Dahmen

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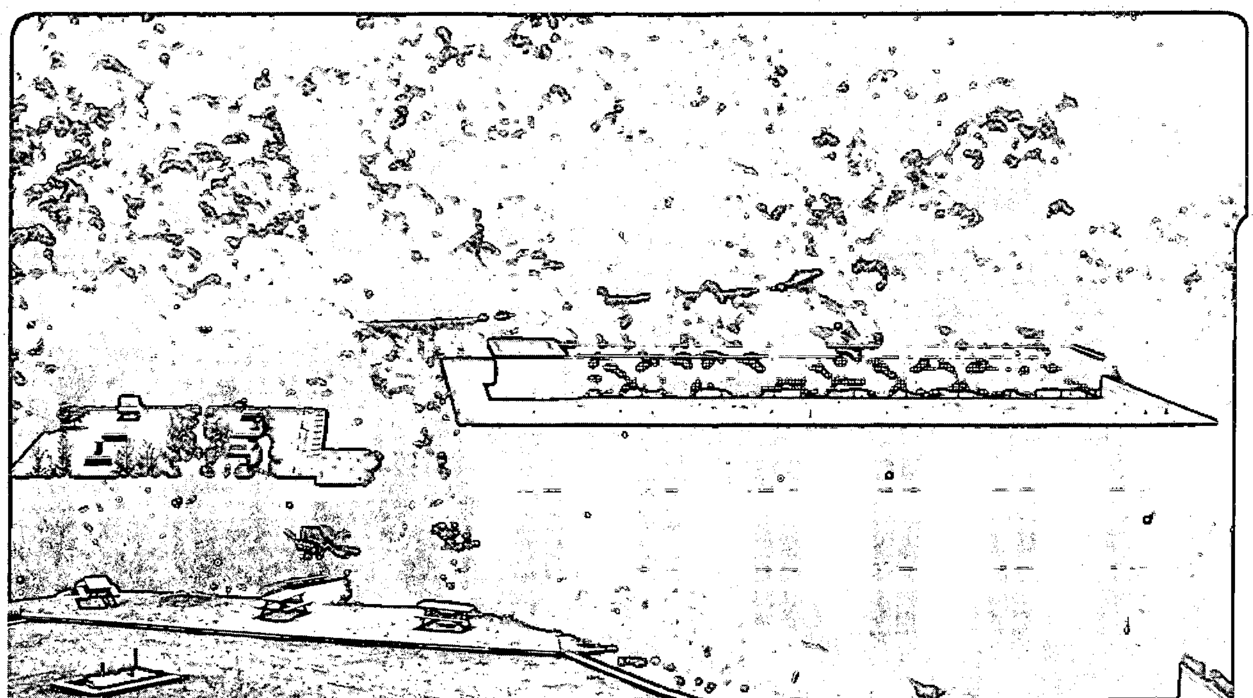



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# Applications of TEM to Interface in Materials

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Proc. MICROMAT III, Rio de Janeiro, Brazil, 28-30 October 1992

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APPLICATIONS OF TEM TO INTERFACES IN MATERIALS

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Interfaces and surfaces play a critical role in the properties and behavior of materials. While surfaces have been investigated by a number of scattering techniques and scanning probe microscopies, the major tool for investigating the structure of *internal* interfaces has been transmission electron microscopy. Most of our current knowledge of the topography and atomic structure of crystalline interfaces has been derived from diffraction contrast, high resolution and selected area or convergent beam diffraction techniques in the transmission electron microscope.

High resolution electron microscopy (HREM) has recently become more prominent because of greatly improved resolution of modern electron microscopes, better means of sample preparation and wider availability of more generally applicable atomistic simulation procedures. As a result, a number of recent investigations have reported new and interesting features of crystalline interfaces and compared them with models based on atomistic, crystallographic or elastic theories. Examples of such features are stand-off dislocations in metal-ceramic [1] interfaces, structural multiplicity of grain boundaries [2], solute segregation to selected facets [3], grain boundary microfaceting and dissociation [4], elastic distortion fields around interfacial ledges [5] and roughening transitions [6].

Several examples of interfacial structure analysis by TEM will be given in this talk. Figure 1 shows a high resolution image of heteroepitaxial interface grown by vapor deposition of Al on a single crystal Si substrate [7]. The interface is seen to be interrupted by amorphous islands, indicating epitaxial growth through pinholes in an oxide surface layer.

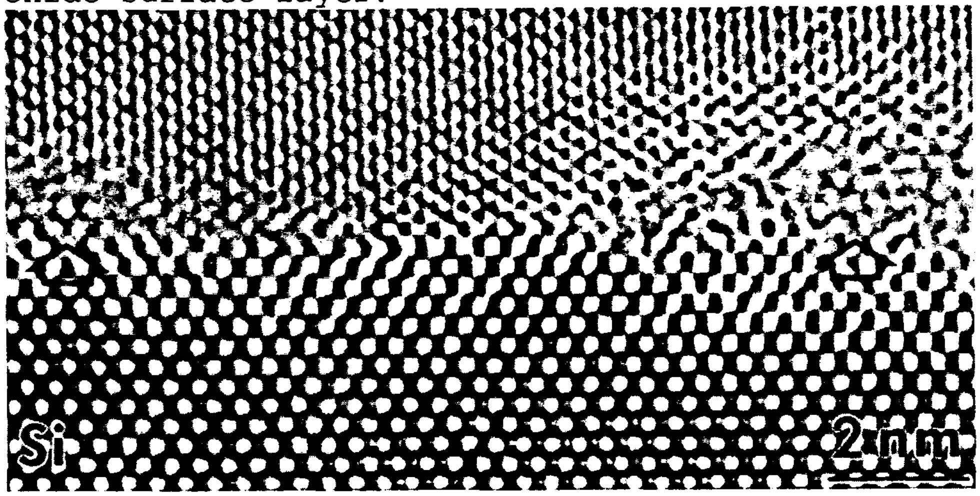


Figure 1. Cross section high resolution micrograph of heteroepitaxial Si-Al interface grown by PVD.

The epitaxial alignment is remarkably good considering the rapid growth rate of the layer. Under much more stringently controlled UHV deposition conditions it is sometimes found that heteroepitaxial interfaces are reconstructed. This reconstruction can be made visible directly in HREM or indirectly from weak diffraction peaks in plan view diffraction patterns.

Interfaces grown by solid state precipitation are usually much cleaner and have a better developed crystallographic structure. Figure 2 shows a high resolution micrograph of epitaxial interfaces between a Ge precipitate and an Al matrix.There is no long-range atomic relaxation, and analysis of this and similar interfaces has so far failed to detect defect localization into dislocations.

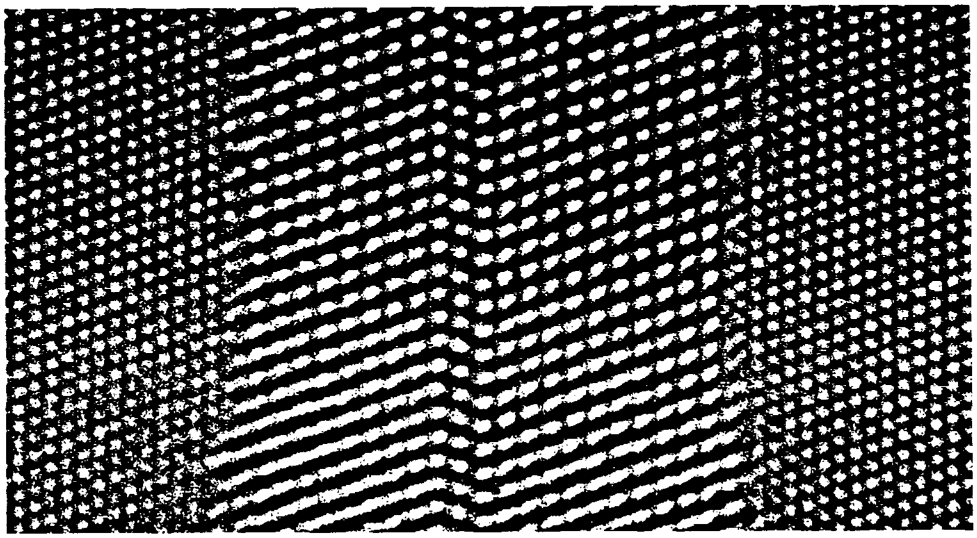

Figure 2. High resolution micrograph of Al/Ge interfaces formed by solid state precipitation.

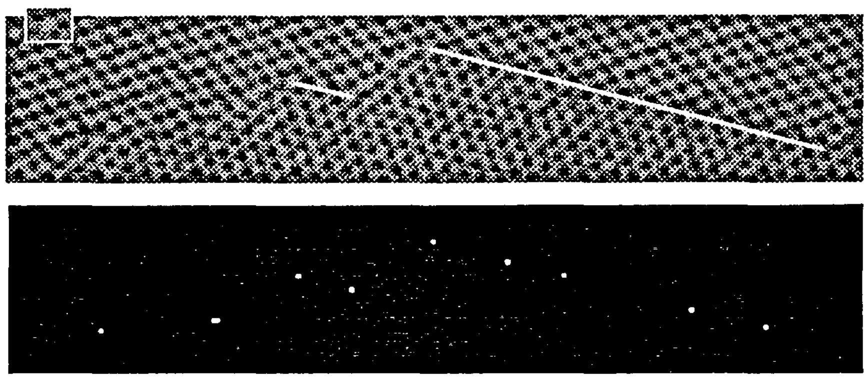

Figure 3. High resolution micrograph of faceted 90° tilt grain boundary in a mazed bicrystal film of Al grown by heteroepitaxial deposition on (100) Si. Template of structural unit is inset in upper left, and cross correlation of the image with the structural unit shown below indicates the location of similar units.

Interfaces between different orientation variants of the films shown in figure 1 form grain boundaries of fixed misorientation but random boundary plane (inclination). Well-annealed mazed bicrystals [8] exhibit pronounced low-energy facets whose detailed atomic structure is being studied by HREM. Figure 3 illustrates a microfaceted 90° tilt boundary in such a mazed bicrystal film of Al. Characteristic structural units are clearly detectable by eye and can be located and quantified in a digitized image by using cross correlation with a template. The template illustrating a structural unit is inset in figure 3, and the location of similar units is indicated by cross correlation peaks below the image.

The location and atomic arrangement of structural units in grain boundaries and the elastic distortions near defects in interfaces are important fundamental aspects of the structure, energy and stability of interfaces in solids. Future developments in electron microscopy will require such structure determination, refinement and quantitative comparison with models to become as routine as multislice image simulations have become in recent years.

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