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LATTICE IMAGE CONTRAST OF ORDERED DOMAINS IN Cu_3Au .

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Although lattice imaging was one of the first techniques in transmission electron microscopy of crystals(1), only with the improved resolution ($\approx 2\text{\AA}$) of modern microscopes has it become possible to obtain the lattice image of metals as a matter of routine. To date fine-scale phenomena in alloys have been studied principally by relating the distortion of the fringe image to the defect in the crystal lattice {e.g. dislocations, radiation induced damage, G-P zones etc. (2)} but considerable controversy exists as to the validity of interpreting the fringes in terms of a one-to-one correspondence with the lattice planes in the specimen. One of the areas of research so far unexplored by this technique is the study of ordering reactions in alloys. The present paper demonstrates how it is particularly useful in this field especially in avoiding the controversy associated with the interpretation of fringe distortions.

Cu_3Au was chosen as a model system. Alternate {200} planes in the ordered structure (Ll_2) are composed of all copper atoms and half copper, half gold. Thus the periodicity in $\langle 100 \rangle$ directions is twice that of the fundamental f.c.c. lattice of the disordered alloy and this periodicity was the one found in the lattice images. Fringe visibility was markedly dependent on a number of factors such as specimen thickness, orientation, the beams used to form the image, underfocus of the objective lens, and the image appearance has been successfully correlated with simulated images using many beam dynamical calculations(3). One important result of this study is that the superlattice fringes were obtained from (000), (100) plus (200) beam images. Thus the possibility arises of studying the ordering reaction using this imaging mode, simultaneously obtaining a lattice image of disordered material with (200) fringe spacing and ordered material with (100) fringe spacing. Examples of such images for partially ordered Cu_3Au are shown in Figure 1, in which a selection is given of a series of images at different objective lens current (focus) settings. The sharpest fringes in the sequence predominantly possess the (200) spacing ($1.9\text{\AA}$) of the disordered f.c.c. lattice (Fig. 1a). However, at approximately $300\text{\AA}$ underfocus of the objective lens (Fig. 1b) a dispersion of discrete regions can be seen ($\approx 20\text{-}30\text{\AA}$ in diameter) in which the fringe spacing is that of the superlattice ($3.8\text{\AA}$). The image in intermediate areas has been lost. These discrete regions are indicated by the lattice image to be ordered domains, and were found to correspond exactly with the bright regions in dark field micrographs taken using the superlattice (100) reflection. At intermediate degrees of underfocus (Fig. 1c) the ordered and disordered regions are imaged simultaneously, with (100) fringe periodicity in the former and (200) fringe periodicity in the latter. The image in the ordered domains is composed of alternately stronger and weaker (200) fringes, which is revealed more clearly by a positive print of the original plate (Fig. 1d). Contrast of the domains is thus enhanced when the matrix is not imaged (Fig. 1b) or in a positive print of the simultaneous image (Fig. 1d). It may also be improved by viewing the normal print at an oblique angle, a representation of which is shown in Fig. 2, the wider white fringes of the ordered domains now appearing more clearly. Lattice imaging has already been successfully utilised in our study of ordering reactions in which the relationship of anti-phase domain distribution and the splitting of superlattice reflections has been directly confirmed and the structural nature of short range order in Cu_3Au has been clarified(4). Financial support for this work from the National Science Foundation and the United States Atomic Energy Commission and photographic assistance from D. Kreitz are gratefully acknowledged.

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FIG. 1(a-c) Lattice images of partially ordered Cu_3Au at varying degrees of objective lens defocus; (d) Positive print of (c).

FIG. 2 Lattice image as Fig. 1c above, photographed at an oblique angle.

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