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FIELD-ION MICROSCOPIC STUDY OF ANTIPARALLEL TWINS IN Ni_4Mo

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ABSTRACT

Ni_4Mo undergoes an order-disorder transformation giving rise to three types of domain boundaries. The field-ion image contrast from one such interface, namely the antiparallel twin boundary, has been studied using computer simulation. Evidence is presented for this effect from the field-ion images of Ni_4Mo.

While field-ion micrographs from concentrated random alloys have been disappointing, the images from ordered alloys reveal excellent detail. Hence several ordered alloys have been examined in the field-ion microscope to understand the mechanism of ordering and defect configuration (1). Out of many ordered alloys that have been examined, Ni_4Mo (2) has been studied in considerable detail. LeFevre et al. (3) have studied the image characteristics of Ni_4Mo and also analyzed the translational antiphase boundary contrast, while a correlation of the mechanical properties with structure using X-ray, electron and field-ion microscopic techniques has been presented by Chakravarti et al. (4). Recently both electron and field-ion microscopy have been used by Okamoto and Thomas (5) to study the nature of short-range order in as quenched Ni_4Mo.

Superlattice formation in Ni_4Mo occurs with a change in lattice symmetry from disordered face-centered cubic lattice to the ordered body-centered tetragonal lattice of the $D1_a$ type. The tetragonal axis is parallel to one

of the cube axes and the other two axes are rotated either positively or negatively by an angle $\theta = 18.4°$. There are 30 possible ways in which the β-phase may nucleate from the disordered α-phase giving rise to a variety of domain boundaries. The various types of interfaces obtained as a result of the ordering process can be classified into three types (6):

(a) Translational antiphase boundaries are obtained when the tetragonal axes of the two domains are parallel but the origin of one domain is on a different sublattice.

(b) Antiparallel twin boundaries are the interfaces obtained when the tetragonal axes are antiparallel to each other and the two a-axes enclose an angle $2\theta = 36.8°C$. The twin planes are (200), (020), (220) and $(2\bar{2}0)$ as referred to the face-centered cubic lattice.

(c) Perpendicular twins are obtained by the impingement of two domains with their c-axes mutually perpendicular to each other.

In an exceedingly elegant demonstration Ruedl et al. (6) derived that the three different types of interfaces give rise to α-fringes, wedge fringes and δ-fringes respectively and presented evidence for their presence from electron micrographs.

The contrast from translational antiphase boundaries in the FIM images can be understood on the basis of the $\bar{g}.\bar{R}$ criterion (7) and LeFevre et al.(3) identified them in Ni_4Mo. LeFevre and Newman (8) made tentative identification of an antiparallel twin by the orientation relationship between the two domains. The presence of perpendicular twins has been inferred by Chakravarti et al. (4) on the basis of their high density of occurrence and their plate-like morphology. It is clear that unambiguous identification from FIM images has not been achieved.

Chandrasekharaiah and Ranganathan (9,10) have used computer simulation as an aid in the interpretation of field-ion images from twin interfaces. One of the major contrast features is the matching of important planes across the boundary. Usually it occurs that m planes of $(h_1k_1\ell_1)$ of one domain match with n planes of $(h_2k_2\ell_2)$ of a second domain where m and n are small integers. While computer simulation has provided ample validity for this theory no experimental evidence has been available to show the matching of planes of dissimilar indices across an interface. It may be noted that 1:1 and 1:2 matching of planes of similar indices across twin and domain boundaries have been reported earlier. It is pleasing, therefore, to report 1:1 matching of (110) plane of one domain with (020) plane of a second domain across an antiparallel twin boundary in ordered Ni_4Mo.

Computer simulation of the six different orientations in Ni_4Mo has been performed (11) and boundaries were introduced across domains of different orientations to correspond to the antiparallel and perpendicular twins. Figure 1 shows the contrast to be expected when two domains meet across antiparallel twin boundaries. The m:n interactions are listed in Table I

TABLE I: Antiparallel Twin Interactions in Ni_4Mo

Domain I		Domain II		Twin Planes			
				$(220)_{fcc}$		$(020)_{fcc}$	
bct	fcc	bct	fcc	m	n	m	n
(020)	(260)	(110)	(240)	4	3	1	1
(130)	(680)	(110)	(240)	7	3	3	1
(110)	(420)	(310)	(860)	3	7	1	2
(110)	(420)	(200)	(620)	3	4	2	3

for two different orientations of the boundary planes. From Figure 1 it is seen that the fundamental planes (marked F) remain unaffected while the prominent superlattice planes give rise to definite interactions.

Figure 2 shows a field-ion image of Ni_4Mo taken at 77°K. A very thin slice of a first domain is seen passing through (110) of domain II. The ledges of the rings within the slice match 1:1 with the (110) rings of domain II. This can be compared with the boundary between $(020)_I$ and $(110)_{II}$ in Fig. 1. Hence, it is concluded that the ledges of rings within the slice belong to (020). This is also in agreement with the expected location of (020) for the antiparallel twin orientation. The twin is extremely narrow (~25Å thick) and brings out the usefulness of FIM in studying the substructure due to ordering. Trace analysis showed that the plane of the boundary was $(020)_{fcc}$.

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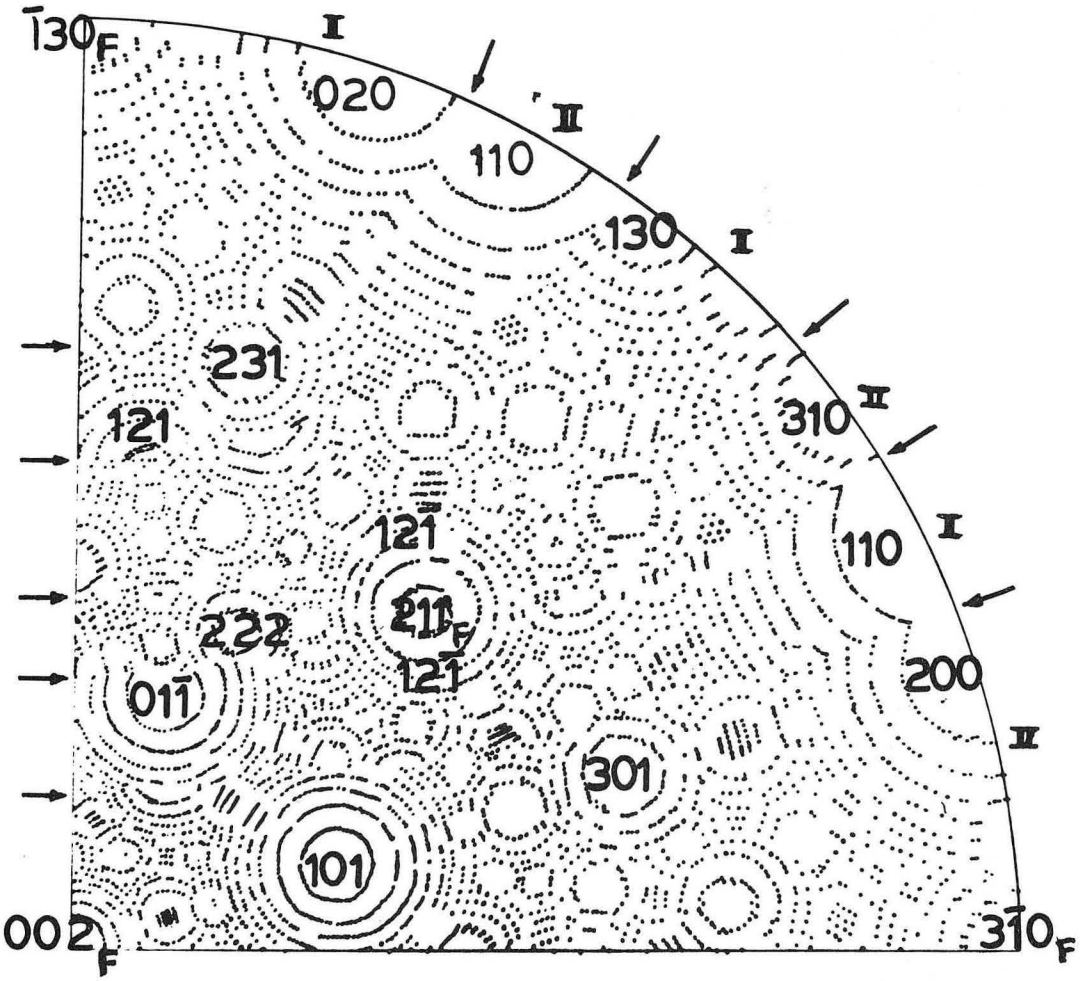

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Fig. 1

Computer simulated field-ion pattern showing antiparallel twin boundaries in Ni_4Mo. Fundamental planes are marked F.

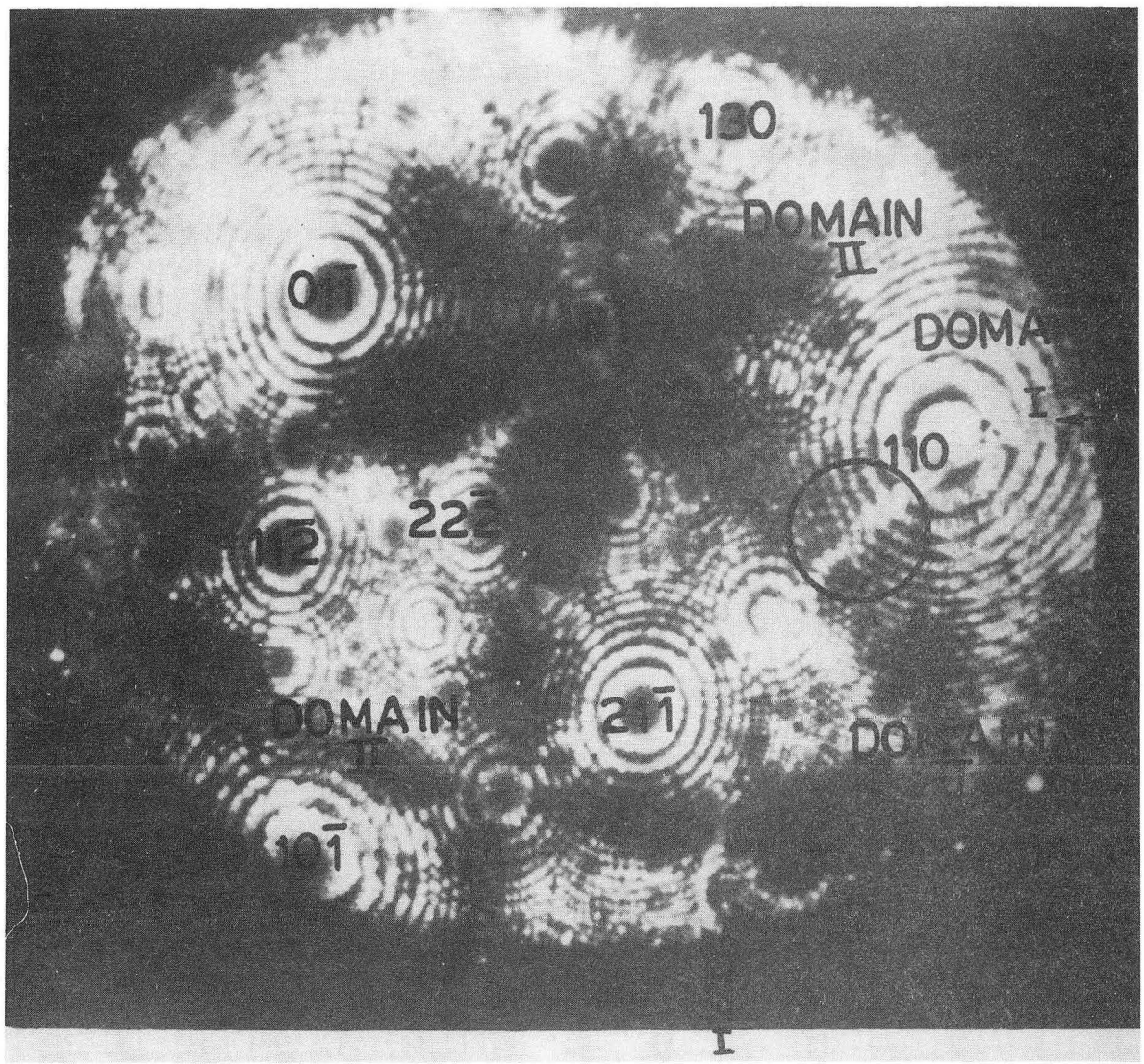

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Fig. 2

Field-ion micrograph in Ni_4Mo showing a thin slice of a second domain matching across antiparallel twin boundaries. The $(110)_{II}$ - $(020)_{I}$ matching region is circled.

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