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On the imaging of composition modulations

Sir,

The purpose of this letter is to present some considerations on an interference contrast mechanism for imaging composition modulations in anisotropic crystalline alloys with the electron microscope.

The use of interference contrast is best exemplified by the well known technique of lattice imaging. Fringes are produced by the 'beating' of the transmitted beam against a diffracted beam. The distance between the fringes corresponds to the interplanar spacing of the diffracting planes. In principle, this contrast mechanism can be used to image any periodic structure.

It is well known that an alloy which is undergoing spinodal decomposition has composition modulations along the elastically soft directions (Cahn, 1961, 1962). These modulations in real space produce satellites in reciprocal space. If the modulations exist in the three mutually perpendicular ‹100› directions in real space (as is the case for most cubic alloys), satellites will exist around each lattice spot in reciprocal space along the ‹100› reciprocal-lattice directions. The satellites arise from both strain modulations and structure-factor modulations (Daniel & Lipson, 1943).

The reciprocal-lattice vector $\Delta\mathbf{g}$ which connects a satellite beam to its corresponding matrix reflection is parallel to the direction of the real-space composition modulation which gave rise to it, and the reciprocal value of its magnitude is equal to the wavelength Λ of the modulation in real space. If one satellite is allowed to interfere with its matrix reflection, a fringe pattern should result (modulation images). The fringes would have a spacing of Λ, and be perpendicular to the vector $\Delta\mathbf{g}$. They correspond to the local composition fluctuations that exist in real space.

The fringes should exist when any beam with satellites is used to form an image. However, the intensity of the satellites around the transmitted beam is usually very weak, since they are only formed from structure-factor modulations. Thus, modulation images would be best obtained with a diffracted beam and an associated satellite (*i.e.* dark-field imaging).

The contrast produced by this mechanism would be overlaid on that produced by other mechanisms (*e.g.* structure-factor differences, thickness differences, or strain effects). If the other sources of contrast are too strong, the modulation images will not be distinguishable. However, modulation imaging is a separate contrast mechanism and should be observable in certain crystalline spinodal systems.

Once the fringes are found, it would be necessary definitely to establish their origin. Modulation images can be differentiated from such things as moiré fringes and thickness fringes by showing that the spacing of the fringes is independent of the choice of **g**. This is so because the satellite spacing is constant. Furthermore, the fringes would have the spacing and direction of the composition modulations, which can be readily ascertained from the diffraction pattern.

Modulation images have not yet been unambiguously observed. The major problem in the alloys studied thus far is that the fringe contrast is too weak, in comparison to the strain contrast (Laughlin, 1973). Further attempts are presently being made to observe modulation images experimentally.

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