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Ashby M F & Brown L M. Diffraction contrast from spherically symmetrical coherency strains. *Phil. Mag.* 8:1083-103, 1963; and On diffraction contrast from inclusions. *Phil. Mag.* 8:1649-76, 1963.
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These papers describe a theory for the appearance in the electron microscope of small precipitates and inclusions in metals, responsible for the strength of engineering metals and alloys. They reveal the early stages of nucleation and growth processes in the solid state. The elastic strains they produce had been a subject of speculation for 15 years or more, ever since the pioneering work of N.F. Mott and F.R.N. Nabarro,[1] and now one could see directly these strains and make an assessment of their magnitude. [The *SCI*® indicates that these papers have been cited in over 420 and 310 publications, respectively.]

Seeing Elastic Strains in the Electron Microscope

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These papers were written because Mike Ashby and I were thrown together in the same house for graduate students and postdocs working in science departments in the University of Cambridge. I had come from the University of Birmingham, where I had finished a PhD under P.L. Pratt on the plasticity of rock salt; but at the same time my other supervisor there, the late J.D. Eshelby, had introduced me to elastic models of defects in solids, which, however, seemed difficult and abstruse to me.[2] Mike had just completed a PhD under G.C. Smith in the Department of Metallurgy in Cambridge, on the topic of the hardening of metals produced by small particles resulting from partial oxidation of dilute alloys of copper with a more oxidisable element such as silicon. This process, called internal oxidation, produced inert spherical silica particles in a pure copper matrix and was ideal for testing theories of the mechanical strength of alloys. In the course of this work, Mike had noticed curious contrast patterns around images of the particles in the electron microscope and had speculated that these were produced by the strain resulting from differential contraction of the copper and the silica upon cooling.

Although I was supposed to be working on the mechanical strength of pure aluminium, in particular what happens at very high temperatures, what really interested me were the new techniques of electron microscopy, then under intensive development. It seemed clear to us that a new age was dawning, in which the theoretical ideas of solid-state physics could be made directly experimentally accessible. And this was what was exciting about the strains around the silica particles: the curious pattern of elastic displacements, exactly analogous to the electric field around a point charge, could be actually seen, and the magnitude of the resulting stresses estimated. I well remember the first diagrams we drew of the bending of the planes around the particles and the recognition that the characteristic "double D" form of the contrast could be understood simply, without detailed mathematics. Suddenly Eshelby's abstruse ideas had taken life. But Archie Howie and Mike Whelan in Hirsch's group had published their epoch-making "dynamical theory of diffraction contrast," and they encouraged us to use that to get a thorough quantitative understanding of what Mike was seeing.[3]

In the space of a few months, Mike and I learned computing and wrote the programs required; we looked at several different examples of the strain contrast (here my aluminium experiments came in handy, because I could look at dislocation loops in aluminium), and we sorted out one very perplexing effect, the so-called "anomalous" contrast, images of a different symmetry that in fact give the sign of the strain. The papers were very satisfying to write and were instantly accepted—unlike most of the papers I have since written, which, if they are accepted at all, seem to require a certain amount of proselytising. Why were the papers instantly accepted? I think it was because they reported an advance in a technique, where the ideas though new were relatively uncontroversial; also, the effects we discussed were very commonly observed by the large numbers of people looking at metallurgical specimens. This aspect of the work concerned with estimating the magnitude of the strains has been less successful and is now only occasionally used; other methods based on Moire patterns are far more accurate.

An interesting extension of the work has been the development of methods for determining the sign of the elastic displacements around small defects. (See, for example, references 4 and 5.)

The observation of strain contrast has become routine, and such topics as the relief of strain by dislocation production have become very widely appreciated in the community. Nowadays, these topics are central to the control of defects in man-made multilayers intended for electronic devices.[6]

1. **Mott N F & Nabarro F R N.** Dislocation theory and transient creep. *Report of a conference on strength of solids held at the H.H. Wills Physical Laboratory, University of Bristol, on 7-9 July 1947.* London: Physical Society, 1948. p. 1-19. (Cited 10 times.)
2. **Eshelby J D.** The determination of the elastic field of an ellipsoidal inclusion. *Proc. Roy. Soc. London Ser. A* 241:376-96, 1957. (Cited 1,165 times.)
3. **Howie A & Whelan M J.** Diffraction contrast of electron microscope images of crystal defects. *Proc. Roy. Soc. London Ser. A* 263:217-37, 1961. (Cited 300 times.)
4. **Mayer R M, Brown L M & Gosele U.** Nucleation and growth of voids by radiation: preface to a series of seven papers. *J. Nucl. Mater.* 95:44-5, 1980. (Cited 10 times.)
5. **Mayer R M & Brown L M.** Nucleation and growth of voids by radiation. I. Formulation of the problem. *J. Nucl. Mater.* 95:46-57, 1980. (Cited 10 times.)
6. **Perovic D D, Weatherly G C, Baribeau J-M & Houghton D C.** Heterogeneous nucleation sources in MBE-grown Ge_xSi_{1-x}/Si strained layer superlattices. *Thin Solid Films* 183:141-56, 1989.

