Identification of eta-carbide in a commercial Ni–Mo alloy (Hastelloy® alloy B-2)

The commercial Hastelloy* alloy B-2 is essentially a Ni–Mo alloy where the carbon content is kept at a low level in order to achieve an acceptable corrosion resistance in the as-welded condition [1]. Recently, a minute amount of the intermetallic NiMo (δ-phase) has been identified in a heat containing less than 0.002 weight per cent carbon [2]. It is the objective of this note to report on the identification by electron diffraction and microscopy of a grain boundary eta-carbide phase in aged samples of a heat containing 0.002 weight per cent carbon.

Table I shows the chemical composition of the heat investigated. The heat treatment consisted of annealing at 1065° C followed by water quenching. Annealed samples were then aged at 800° C for 1 to 100 h. Thin foils for transmission electron microscopy and diffraction were prepared by jet polishing in a solution consisting of one part HNO_3 and three parts methanol at about − 30° C. All the foils were examined in a Philips 300EM operated at 100 kV.

Fig. 1 shows a number of selected area diffraction patterns derived at different tilts from the grain boundary particle shown in Fig. 2. All of these patterns were consistently indexed in terms of a face-centred cubic lattice. The matrix phase (f c c with $a = 0.3610$ nm) was used as an internal

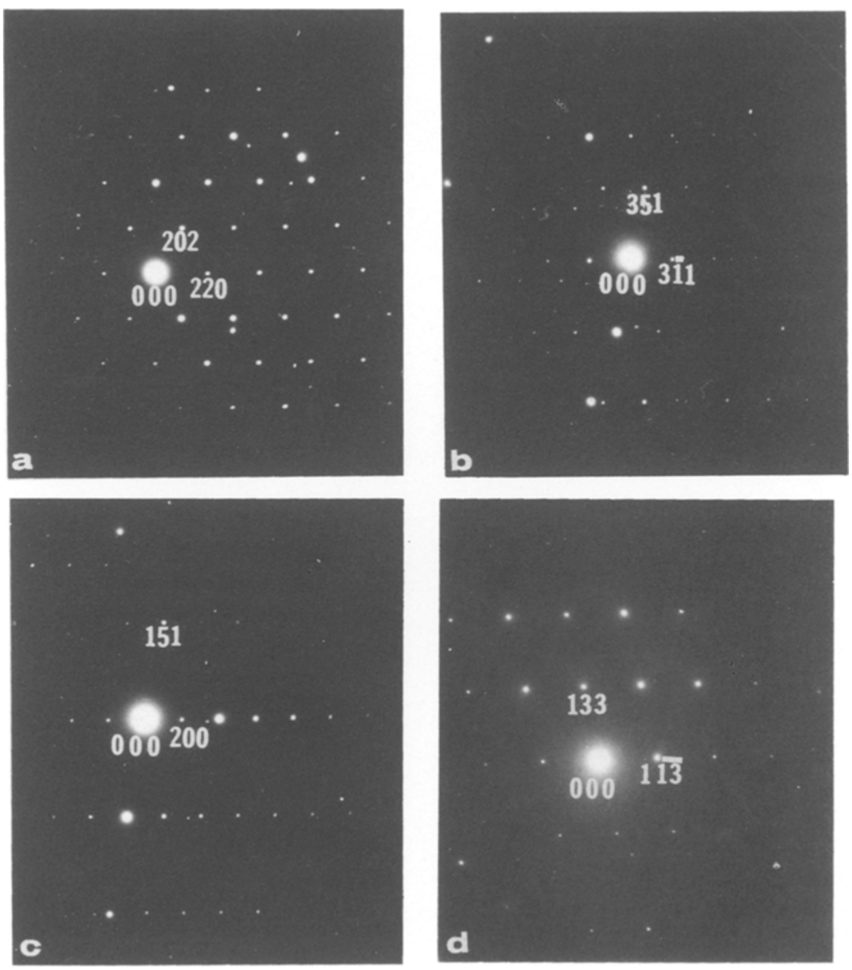

Figure 1 Selected area electron diffraction patterns derived from a grain boundary carbide particle. (a) $[1\bar{1}\bar{1}]$, (b) $[\bar{1}03]$, (c) $[0\bar{1}5]$ and (d) $[\bar{3}3\bar{2}]$.

*Hastelloy is a registered trademark of Cabot Corporation

0022–2461/81/041117–02$02.20/0

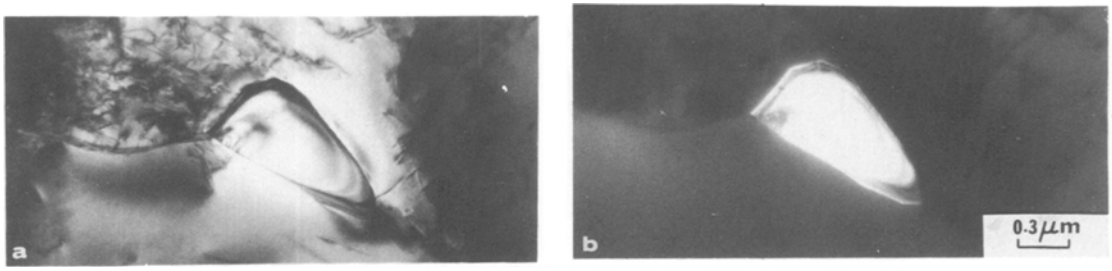

Figure 2 Electron micrographs of the same grain boundary carbide particle as in Fig. 1 (beam parallel to $[1\bar{1}\bar{1}]$). (a) Bright-field image and (b) dark-field image with a (220) particle reflection.

TABLE I Chemical composition in weight per cent

Ni	Mo	Fe	Cr	Co	Si	V	C
70.42	29.92	0.93	0.64	< 0.10	< 0.02	< 0.01	0.002

standard in measuring the camera constant. From the observed *d*-spacings, the lattice constant of the grain boundary phase was calculated to be 10.86 ± 0.01 Å (1.086 nm). This suggests that this phase is an eta-carbide of the form $M_{12}C$ such as that found in the ternary Ni–Mo–C system [3, 4] and in Hastelloy alloy N [5]. The present result and that reported earlier [2] concerning the presence of δ-NiMo in Hastelloy alloy B-2 seem to indicate that $M_{12}C$ and δ-NiMo may co-exist, as has been concluded by Heijwegen and Rieck [4] in the case of the Ni–Mo–C ternary system.

References

1. F. G. HODGE and R. W. KIRCHNER, *Mater. Perfor.* **15** (1976) 40.
2. H. M. TAWANCY, *J. Mater. Sci.* **15** (1980) 2597.
3. A. C. FRACKER and H. H. STADELAMAIR, *Trans. AIME* **245** (1969) 847.
4. C. P. HEIJWEGEN and G. D. RIECK, *Met. Trans.* **4** (1973) 2159.
5. J. M. LEITNAKER, G. A. DOLTER, D. J. BRADLEY, J. C. FRANKLIN and W. R. LAING, *ibid.* **9A** (1978) 397.

Received 19 June
and accepted 30 July 1980

H. M. TAWANCY
High Technology Materials Division,
Cabot Corporation,
Kokomo,
Indiana 46901,
USA

About the origin of magnetoresistance in relatively thin metal films

It has previously been [1] shown that the transport properties of a thin metallic film placed in a transverse magnetic field (perpendicular to its plane) can be, as in the absence of a magnetic field, described in terms of a mean free path model [1, 2] which takes into account the background scattering and the scattering at external surfaces [3, 4], i.e. the scatterings of the Fuchs–Sondheimer conduction model [4]. In this model the film conductivity, σ_F, and the Hall coefficient, R_{HF}, are evaluated by means of the following analytical expressions [1]

$$\sigma_F/\sigma_0 = [A^2 + \alpha^2 B^2]A^{-1} \qquad (1)$$

and

$$R_{HF}/R_{H0} = B[A^2 + \alpha^2 B^2]^{-1}, \qquad (2)$$

where

$$A = \frac{3}{2}\Bigg\{ -\tfrac{1}{2}\mu + \mu^2 + \frac{\mu}{2}(1 - \mu^2 + \alpha^2\mu^2) \times \ln\left[\frac{(1+\mu^{-1})^2 + \alpha^2}{1+\alpha^2}\right] - 2\alpha\mu^3 \arctan\left[\frac{\alpha}{\mu}\,\frac{1}{(\alpha^2 + 1 + \mu^{-1})}\right]\Bigg\} \qquad (3)$$