understood, assuming that the hydroxide film covers only parts of the cathode. The exposed areas exhibit the "large" grain size similar to that found by [2], in which case the inhibitive effect was eliminated by the Cl^- ions in the electrolyte ([5], p. 114).

Although frequent twinning was seen in the "large" grains in many samples, the densities of twin faults found in earlier work [1] cannot be confirmed because no individual faults could be observed. The twin fault densities computed from the densities of the observed "ordinary" twin boundaries are rather low. However, the overall densities can be essentially raised by possible twinning in the "small" grains, predominant in structures in which measurable fault densities were reported in [1]. In fact, observations by Zieler ([3], p. 1155) support twinning in small grains of samples electrolysed from solution containing additives.

On the other hand, numerous "stacking faults" rather than twins were reported in "large" grains in structures electrolysed from Watts solution by Maurin and Froment ([2], p. 107). However, the evidence for their presence in transmission pictures is not given, and it is not certain whether the faults mentioned are really individual stacking faults.

Although it is difficult to make a good estimate of the average grain size from the pictures exhibiting the dual grain morphology, the results of the X-ray measurements of the average particle sizes in [1] are roughly in agreement with qualitative estimates.

The roughly isotropic grain size of the "small" grains is in agreement with the X-ray results.

Conclusions

In conclusion, during the electrolysis of nickel from acid sulphate solutions, the coverage of the cathode by a possible colloidal film of nickel hydroxide is the decisive factor. In its presence, the cathode exhibits a very fine-grained, randomly oriented structure. If the film is removed, the structure consists at these current densities of relatively large grains with a very strong texture [100] perpendicular to cathode. The large grains are often twinned, but no individual stacking faults are found.

The inhibitive action of the hydroxide film can be eliminated by chloride ions [2], or it can be replaced by an organic additive [3].

Acknowledgements

This research was supported by the National Research Council for Technical Sciences (Finland). The authors express their thanks to Professor H. Miekk-oja (Head of the Laboratory for Physical Metallurgy, Institute of Technology) for the use of the electron microscope. Thanks are also due to the Metallurgical Research Centre of the Outokumpu Company for preparing the cathodes.

References

1. E. J. SUONINEN, *J. Matls. Sci.* **2** (1967) 44.
2. G. MAURIN and M. FROMENT, *Métaux* **42** (1966) 102.
3. J. A. CROSSLEY, P. A. BROOK, and J. W. CUTHBERTSON, *Electrochim. Acta* **11** (1966) 1153.
4. J. K. DENNIS and J. J. FUGGLE, *Electroplating and Metal Finishing* (January 1968) p. 16.
5. H. FISCHER, "Elektrolytische Abscheidung und Elektrokristallisation von Metallen" (Springer, Berlin, 1954).

20 February 1967

E. J. SUONINEN
Institute of Technical Physics
University of Oulu, Oulu, Finland

T. HAKKARAINEN
Laboratory of Physical Metallurgy
Institute of Technology
Otaniemi, Finland

Preparation of Gold Films with Low Dislocation Densities

The growth of single-crystal films on single-crystal substrates usually begins with the generation of three-dimensional nuclei [1] and proceeds with the growth and coalescence of these nuclei. Complete films that grow in this way contain about 10^{10} dislocation lines per cm^2 [2-5]. They may also contain wide stacking faults and numerous microtwins. Studies of the generation of dislocations, stacking faults and twins have shown that most of them result from the presence of three dimensional nuclei whose lattices are either rotated relative to one another or are displaced from one another by non-lattice vectors [4, 6-8]. It is clear that the defect content of complete films would be reduced if the initial deposit did not contain nuclei that were either misaligned or displaced from one another. One of the ways of eliminating these nuclei is to ensure firstly that there is little or no barrier to nucleation and secondly that the misfit between the overgrowth and substrate lattices is small (less than about 4%). Under these conditions the initial deposit is expected to grow on the substrate in much the same way as the substrate would grow on itself. The deposit would exhibit monolayer-like growth, and its initial layers would be strained to exactly fit the substrate lattice [9]. Specimens in which this mode of growth has been observed are deposits of gold on silver [10]. The aim of this letter is to show that gold films grown on annealed silver surfaces can have dislocation densities much lower than 10^{10} per cm^2.

The specimen was prepared in the following way. A silver pellet was melted in vacuum and etched to remove the impure surface layer. It was then remelted, cooled slowly to room temperature, and coated with gold. The pressure in the chamber was 2×10^{-10} torr prior to the deposition of gold. It was less than 5×10^{-8} torr during the growth of the gold film. After the specimen had been removed from the chamber, the silver was dissolved in nitric acid, and the free gold film mounted for transmission electron microscopy.

The specimen was found to be much more perfect than gold films under similar vacuum conditions but on sodium chloride cleaved in air [5]. The dislocation density varied from one part of the specimen to the other, but there were almost invariably fewer than 10^8 dislocation lines per cm^2 of film area. Some of the more perfect areas contained less than 10^7 dislocations per cm^2. A micrograph of a portion of the gold film is shown in the figure. One of the few dislocations present in the area is labelled D. There are no twins or stacking faults.

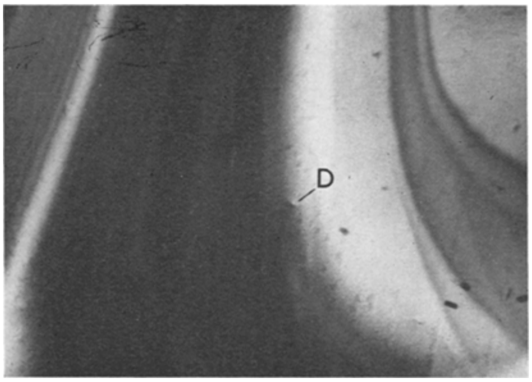

Figure 1 A gold film grown at room temperature on an annealed silver pellet. The silver surface was prepared inside the vacuum chamber, and the pressure during the growth of the gold film was less than 5×10^{-8} torr (× 10000).

Acknowledgements

The author would like to thank Professor F. R. N. Nabarro for his encouragement and advice, and to thank the Council for Scientific and Industrial Research, Pretoria, for financial support.

References

1. D. W. PASHLEY, *Adv. Phy.* **14** (1965) 327.
2. D. W. PASHLEY, J. W. MENTER, and G. A. BASSETT, *Nature* (1957) 179.
3. G. A. BASSETT, J. W. MENTER, and D. W. PASHLEY, *Proc. Roy. Soc.* **246** A (1958) 345.
4. J. W. MATTHEWS, *Phil. Mag.* **4** (1959) 1017; *ibid* **7** (1962) 915.
5. J. W. MATTHEWS and E. GRUNBAUM, *ibid* **11** (1965) 1233.
6. G. A. BASSETT, Proc. Eur. Reg. Conf. on Electron Microscopy (Delft, 1960) (De Nederlandse Vereniging voor Electronenmicroscopie, Delft) **1** (1961) 270.
7. J. W. MATTHEWS and D. L. ALLINSON, *Phil. Mag.* **8** (1963) 1283.
8. M. H. JACOBS, D. W. PASHLEY, and M. J. STOWELL, *ibid* **13** (1966) 121.
9. J. H. VAN DER MERWE, *J. Appl. Phys.* **34** (1963) 117.
10. J. W. MATTHEWS, *Phil. Mag.* **13** (1966) 1207.

12 March 1968

J. W. MATTHEWS
Department of Physics
University of the Witwatersrand
Johannesburg, South Africa