

Brothers Asbestos) for his part in deriving the statistical analysis.

A. W. ATKINSON
R. B. GETTINS
A. L. RICKARDS

Turner Brothers Asbestos Co. Ltd,
Rochdale, Lancashire.

Received March 13, 1970.

¹ Whittaker, E. J. W., *Acta Cryst.*, **10**, 149 (1957).

² Keiji, Y., *Acta Cryst.*, **23**, 704 (1967).

³ Wronski, J. P., *Asbestos*, **50** (2), 3 (1968).

⁴ Aveston, J., *J. Mater. Sci.*, **4**, 625 (1969).

⁵ Bobkowitz, A. J., and Gauvin, V. H., *Chem. Eng. Sci.*, **22**, 229 (1967).

⁶ Burgers, J. M., *Second Report on Viscosity and Plasticity* (Nordemann, New York, 1938).

⁷ Blakeney, W. J., *J. Colloid Interface Sci.*, **22**, 324 (1966).

Melting of Very Small Particles during Evaporation at Constant Temperature

THE dependence of the melting point of small solid particles on their size is implicit in the work of J. J. Thomson¹ on the effect of size on phase equilibria. It has been shown that large depressions of melting point are found when the diameters of the particles are about 20 nm. Takagi² and Blackman and Curzon³ used electron diffraction techniques to study the melting of such small particles. The particle sizes in the latter case were determined by electron microscopy. Further systematic studies have been carried out by Wronski⁴ with tin, and by C. J. Coombes (private communication) on lead (see also refs. 5-7).

A new method for observing the melting point of individual gold particles is described in this communication. Particles of solid gold were maintained at a constant temperature, somewhat below the bulk melting point, in a JEM 6A electron microscope. At this temperature, the rate of change in the size of the particles, caused by their evaporation, can be conveniently measured (see ref. 8 for similar measurements on silver). Instead of the monotonic evaporation curves of the kind found for silver particles, the results showed a distinct change in the rate of evaporation of particles (see Fig. 1) at a size which was dependent on temperature.

The change in evaporation rate is caused by melting of the gold particles. This change occurs because the solid gold particles have an evaporation coefficient less than unity⁹, while the molten particles have an evaporation coefficient of unity.

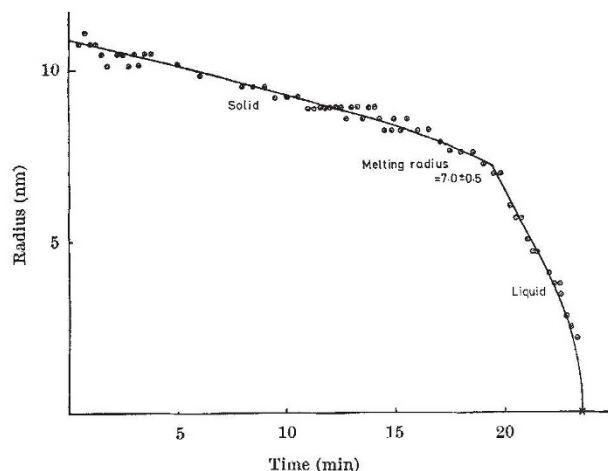


Fig. 1. The evaporation of a gold particle, $T = 1,229 \pm 5$ K. X marks the time when the particle became unresolved in the electron microscope image.

A series of experiments were carried out at different temperatures (T) over the range 1,150 to 1,330 K. These temperatures were determined from the rate of evaporation of the liquid particles; the radius of a particle at the melting point was taken at the sudden change in the rate of the evaporation curves.

It is to be expected that the reduced temperature, T/T_m (T_m being the bulk melting temperature), plotted as a function of the radius would give a universal curve for materials with similar properties and similar crystal structure. The results of Coombes (private communication), for lead, fit within experimental error the curve drawn for gold; surprisingly, the data for tin found by Wronski⁴ also fit the same curve.

A detailed account of this work will be published later. One of us (J. R. S.) thanks the Science Research Council for a maintenance grant.

M. BLACKMAN
J. R. SAMBLES

Department of Physics,
Imperial College,
London SW7.

Received April 7, 1970.

¹ Thomson, J. J., *Applications of Dynamics to Physics and Chemistry*, 259 (Macmillan and Co., London, 1888).

² Takagi, M., *J. Phys. Soc. Japan*, **9**, 359 (1954).

³ Blackman, M., and Curzon, A. E., *Structure and Properties of Thin Films* (edit. by Neugebauer, C., Newkirk, J. B., and Vermilyea, D. A.), 217 (Wiley and Sons Inc., 1959).

⁴ Wronski, C. R. M., *Brit. J. App. Phys.*, **18**, 1731 (1967).

⁵ Gladkikh, N. T., Niedermayer, R., and Spiegel, K., *Phys. Stat. Sol.*, **15**, 181 (1966).

⁶ Boiko, B. T., Pugachev, A. T., and Bratsykhin, V. M., *Sov. Phys. Sol. Stat.*, **10**, 2832 (1969).

⁷ Póczya, J. F., Barna, A., and Barna, P. B., *J. Vac. Sci. Tech.*, **6**, 472 (1969).

⁸ Blackman, M., Lisgarten, N. D., and Skinner, L. M., *Nature*, **217**, 1245 (1968).

⁹ Schwoebel, R. L., *Surf. Sci.*, **2**, 356 (1964).

Increasing Permeability of Polymer Membranes by Irradiation in the Fully Swollen State

THE permeability of polyolefin film may be made selective towards a particular solvent by annealing the film below its dissolution temperature in that solvent. For example^{1,2}, a selectivity towards *p*-xylene in a mixture of *o*, *m* and *p*-xylenes has been conferred on a polyolefin membrane in this way. Michaels and co-workers³ have extended this to other solvents and were able to increase permeability as much as fifteen-fold relative to untreated membranes, but with reduced selectivity toward the permeants. These enhanced permeabilities were, however, not permanent. We demonstrate here⁴ that when solvent annealing of a polyethylene film is followed by cobalt-60 γ -irradiation—while the film is still in contact with the annealing solvent—permeabilities are greatly increased. The enhancement produced by a combination of irradiation and annealing, however, is not only greater than that caused by annealing alone, but is far more permanent.

Polyethylene films were pretreated by soaking for about 48 h in solvent and then irradiated for different times in the same solvent. After irradiation, the films were dried before being placed in the permeation medium, except when this medium was identical with the irradiation solvent.

All permeation measurements and annealing of films were carried out at 30° C. During irradiation, the temperature of the medium fluctuated between 33° C and 38° C; the higher temperatures resulted from γ -ray heating but were not large enough to account for the observed increases in permeability. The experimental procedure and apparatus have been described⁵. The technique eliminated non-