The influence of boron on the nucleation of radiation damage in graphite

by

A. Kelly and R.M. Mayer

Department of Metallurgy,
University of Cambridge,
England.

It has been suggested (Thrower, P.A. (1964) J. Nucl. Mats. 12 56) that boron impurity in graphite single crystals can act as an efficient nucleating agent for defect clusters. Direct evidence for this has been obtained and experiments conducted to investigate why boron should act in this way.

Purified graphite single crystals have been doped with either boron 10 or boron 11 isotopes in the range 10^{-5} to 10^{-2} atom per cent. Electrical resistance and Hall coefficient measurements showed that the boron entered the lattice substitutionally.

Irradiation with neutrons has been carried out at 650°C and 900°C to a fast neutron flux of 7.6 x 10^{19} neutrons/cm^2 and estimated thermal flux of 2.5 x 10^{20} neutrons/cm^2. Crystals containing 1% boron 10, but not those containing 1% boron 11, broke up during irradiation at 650°C. Electron microscopy revealed that the number of interstitial clusters increased and the cluster size decreased with increasing boron content.

The microstructure revealed further differences on annealing between crystals doped with boron 10 and those doped with boron 11. For the boron 10 doped crystals, there is a critical amount of boron above which the volume fraction of damage seen in the electron microscope increases rather than decreases with annealing temperature up to 2000°C. For the boron 11-doped crystals, the volume fraction of interstitial clusters decreased slowly until 1700°C and then much more rapidly. At annealing temperatures greater than 2000°C, the volume fraction increases again if the boron 11 content is about 1%. These loops are much larger than the original clusters and have vacancy character.

The transmutation which boron 10 undergoes with thermal neutrons is not responsible for the enhanced nucleation of the clusters on irradiation since the nucleation is the same for crystals doped with similar amounts of boron 11. The generation rate of defects will however be enhanced by carbon atom displacements caused by energetic lithium and helium atoms in the B^{10} (n, α) reaction. It is likely that this faster rate of damage can account for the differences described above between the boron 10 and boron 11 doped crystals.