precursors used as starting materials gave only a very broad peak at about $2\theta = 19^\circ$, which is far from the 002 reflection produced by graphite. The structure model of the glassy carbon has been proposed by several investigators [6, 7]. The models are derived from results obtained from the radial distribution curve of glassy carbon heat treated at various temperatures between 500 and 3000° C. Noda and Inagaki [6] proposed the model consisting of a large amount of tetrahedral carbon atoms and a number of small domains of trigonal carbon atoms. The model of Furukawa [7] consists of a three-dimensional irregular network configuration which contains all kinds of C–C bonds. The trigonal carbon atom content in glassy carbon increases on raising the heat treatment temperature.

The present experiments gave evidence for the conversion of the carbon precursor to the diamond phase when it was subjected to strong explosively generated shock. This suggests that the cubic diamond may be synthesized by a mechanism other than the diffusionless mechanism or martenstic transformation.

Acknowledgements
This work was sponsored by the Special Fund for Multiminsterial Projects in Japan. The authors would like to thank Mr M. Araki of Nippon Oil and Fats Corporation for technical support of shock compression.

References

1. E. J. WHEELER and D. LEWIS, *Mater. Res. Bull.* **10** (1975) 687.
2. R. S. DeCARLI and J. C. JAMIESON, *Science* **9** (1961) 1821.
3. T. AKASHI, A. SAWAOKA, S. SAITO and M. ARAKI, *Japan J. Appl. Phys.* **5** (1976) 891.
4. N. SETAKA and Y. SEKIKAWA, *J. Amer. Ceram. Soc.* **63** (1980) 238.
5. G. E. DUVALL and G. R. FOWLES, in "High Pressure Physics and Chemistry", Vol. 2, edited by R. S. Bradley (Academic Press, New York, 1963) p. 209.
6. T. NODA and M. INAGAKI, *Bull. Chem. Soc. Japan* **37** (1964) 1534.
7. K. FURUKAWA, *Nihon Kessho Gakkai* **6** (1964) 101.

Received 6 October
and accepted 14 November 1980

NUBUO SETAKA
YOSHIZO SEKIKAWA
National Institute for Researches in Inorganic Materials,
Namiki 1-1, Saknia-mura,
Ibaraki,
Japan

Leached "Syndite" (sintered diamond) as a heat sink material

Some electronic devices are kept cool by mounting them on thin slices of type-2a diamond which act as heat spreaders and are commonly called heat sinks. Whilst this is a successful technique it is only commercially viable for slices up to about 1 mm square. The electrical insulation of the diamond is sometimes important. Other electrically insulating heat sinks are made from beryllium oxide for which there is less limitation on size, but its heat conductivity [1] is not as high as diamond and the material is toxic. This note discusses the possibility of making large heat sinks from the sintered diamond products which are now commercially available and which are known to have a high thermal conductivity [2]. This suggestion has also been made by Pope *et al.* [3, 4].

Most of the sintered diamond materials have a metal matrix (usually cobalt) and so they are electrically conducting. The metal therefore has to be leached out (from the surface at least) if an electrically insulating heat sink is required.

In our investigations the de Beers sintered diamond product "Syndite" was used. The cobalt content before and after leaching was determined both by magnetization measurements (Oxford) and by neutron activation analysis (Amsterdam). The leaching was done with hot aqua regia in a pressure vessel followed by fused sodium nitrate (Oxford) and by hydrofluoric acid and hot aqua regia (Amsterdam). The initial cobalt content was about 12 wt% (5.5 vol%) which reduced to values in the range 2 to 6 wt% after leaching. The electrical resistivity which was originally of the order of 10^{-2} ohm m, increased to about 10^4 ohm m, although in one or two samples the resistivity

0022–2461/81/061730–02$02.20/0

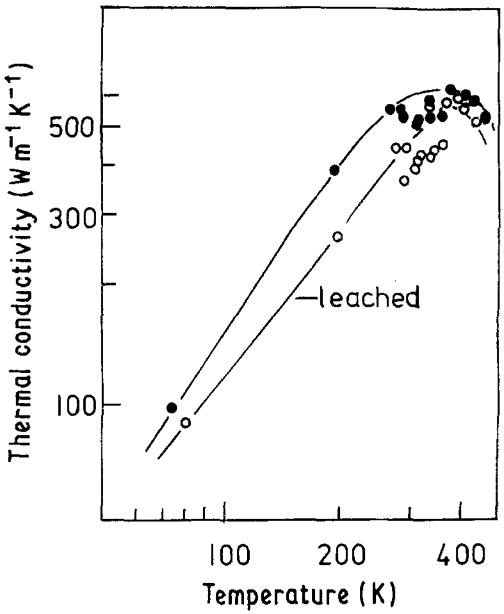

Figure 1 The thermal conductivity of Syndite before leaching (filled circles) and after leaching (open circles).

reached 10^6 to 10^8 ohm m. The behaviour of the leached material was slightly non-ohmic.

It was found that leaching did not cause any disintigration of the Syndite. This is consistent with microscopic observations [5] that the diamond particles in this material have grown together during the manufacturing process to form a polycrystalline diamond material.

The thermal conductivity was measured using a conventional Searle's bar technique. Copper–constantan thermocouples were employed from 80 to 373 K (Oxford) and radiation thermometry was used from about 320 to 480 K (Amsterdam). Results for a typical sample both before and after leaching are shown in Fig. 1. The conductivity drops by about 5 to 10% on leaching but it still has a value of about 500 W m^{-1} K^{-1} at room temperature. This is better than the thermal conductivity of copper (400 W m^{-1} K^{-1}), but lower than for single crystals of type-2a diamond (2100 W m^{-1}K^{-1}) [6, 7].

The top and bottom faces of the leached Syndite samples were metallized with a multilayer structure of Ti, Pt and Au, as currently used for heat sinks of single crystals of diamond [8]. The Au (outer) layers give bondability of a device to the leached Syndite and, in turn, of the leached Syndite to a further substrate such as copper. The electrical insulation of the leached Syndite with these metallized layers remained satisfactory.

It would therefore appear that leached Syndite might be very suitable for use as a relatively inexpensive, large, heat sink for several kinds of electronic device. It could replace the toxic beryllium oxide at present in use for devices requiring electrical insulation and good heat removal.

Acknowledgements

We should like to thank de Beers Industrial Diamond Division Ltd for providing us with some of the Syndite samples. We are grateful to Professor H. A. Das and Mr J. Zonderhuis (Netherlands Energy Research Foundation ECN, Petten) for carrying out the neutron activation analysis, to Mr F. A. Howe and Dr R. C. Woods (Clarendon Laboratory, Oxford) for making the magnetization measurements and to Mr C. I. Nicholls (Clarendon Laboratory, Oxford) for assistance with some of the thermal conductivity measurements.

References

1. G. A. SLACK and S. B. AUSTERMAN, *J. Appl. Phys.* **42** (1971) 4713.
2. E. A. BURGEMEISTER, *Ind. Diamond Rev.* March 1980, 87–9.
3. B. J. POPE, M. D. HORTON, H. T. HALL, S. DIVITA, L. S. BOWMAN and H. N. ADANIYA, *Rev. Phys. Chem. Japan* **S1** (1977) 404.
4. B. J. POPE, M. D. HORTON and H. T. HALL, US Patent No. 4104 344 (1978).
5. C. A. BROOKES and R. M. HOOPER, unpublished work.
6. R. BERMAN and M. MARTINEZ, *Diamond Res.* (1976) 7. (Industrial Diamond Information Bureau).
7. E. A. BURGEMEISTER, *Physica* **93B** (1978) 165.
8. *Idem, J. Phys. D: Appl. Phys.* **10** (1977) 1923.

Received 13 October
and accepted 14 November 1980

E. A. BURGEMEISTER
D. Drukker en Zn.,
Amsterdam,
The Netherlands

H. M. ROSENBERG
The Clarendon Laboratory,
University of Oxford,
Oxford, UK