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Abstract

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PHYSICS

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X-Ray Study of Radiation Damage in Beryllium Oxide

Despite the existence of numerous works devoted to the study of irradiated beryllium oxide (¹⁻¹⁰) and others), the mechanism of radiation damage in BeO is still not completely clear.

Blocks of sintered beryllium oxide, after irradiation at a temperature below 100° by a fast-neutron flux (f.n.) of $2 \cdot 10^{21}$ f.n./cm², turned into powder. On an unirradiated specimen, using a metallographic microscope and by counting the number of reflections on a Debye ring, the grain size was determined; it proved to be $\sim 100 \mu$. Measurement of the sizes of the powder particles into which the BeO specimen had crumbled gave the same value, 100 μ .

Table 1

Line indices	Line width before irradiation	Line width $nvt = 2 \cdot 10^{21}$	Line indices	Line width before irradiation	Line width $nvt = 2 \cdot 10^{21}$
010	12	14	110	17	23
002	16	57	013	19	109
011	15	20	020	21	26
012	16	63	112	22	81

The x-ray study also showed that each powder particle is a single crystal. This fact supports the view of an intergranular mechanism of destruction (^{3,10}). The powder was examined on a diffractometer, on which unirradiated BeO specimens were also examined. The character of the diffraction lines of the initial BeO indicates an undistorted structure (Fig. 1a). Irradiation led to broadening of the diffraction lines and a decrease in their intensity. For all angles $2\theta > 95^\circ$, diffraction maxima do not appear above the background level. The broadening of the maxima is sharply anisotropic. From consideration of Table 1 and Fig. 1 it is evident that the (010) line almost did not change its width, whereas the (002) line became 3.5 times broader (no corrections for doublet structure

Fig. 3. Laue photograph from a BeO powder particle about 70μ in size after irradiation with an integrated flux of $\sim 2 \cdot 10^{21} \text{ n/cm}^2$

Figure 1: Fig. 3. Laue photograph from a BeO powder particle about 70μ in size after irradiation with an integrated flux of $\sim 2 \cdot 10^{21} \text{ n/cm}^2$

Figure 1

Figure 2: Figure 1

were introduced). The degree of broadening of the remaining lines depends on the angle of inclination of the diffracting plane to the basal plane, as is clearly seen from the example of the reflections (011), (012), (013), for which, with increasing third index, the ratios of the line widths of the irradiated and unirradiated specimens are respectively 1.3, 3.9, and 5.7. These results are in qualitative agreement with the data of ⁽⁶⁾. The indicated anisotropic broadening is observed on x-ray patterns of powder consisting of separate free crystals and, thus, is not a consequence of intergranular stresses causing the destruction of sintered beryllium oxide. Apparently, it is the result of internal distortions of the BeO lattice.

When irradiated specimens are recorded on a diffractometer, beginning with an integral flux of $2 \cdot 10^{20} \text{ f.n./cm}^2$, the broadening of the (002) line has a complex character: the line consists, as it were, of two components (Fig. 2). The first, on the side of smaller angles, corresponding to a larger value of the parameter c , is a narrow line with a well-defined maximum. On the side of larger angles it is accompanied by a broader band. As the irradiation dose increases, the intensity of this second component increases at the expense of the first line, and already at an integral flux of $9 \cdot 10^{20} \text{ f.n./cm}^2$ only the broadened component remains, similar to that shown in Fig. 1 for an integral flux of $2 \cdot 10^{21} \text{ f.n./cm}^2$.

Fig. 3. Laue photograph from a BeO powder particle about 70μ in size after irradiation with an integrated flux of $\sim 2 \cdot 10^{21} \text{ n/cm}^2$.

Simultaneously with the anisotropy of line broadening, an anisotropy of the increase in the lattice parameters was also observed. If the calculations are carried out from the position of the center of gravity of the lines, then for fluences of $\sim 10^{21} \text{ n/cm}^2$ we obtain values $\Delta a/a = 0.26\%$ and $\Delta c/c = 0.41\%$. If the parameter c is calculated from the position of the peak of the small-angle component of the (002) line, then one obtains

Fig. 1. Profiles of diffraction lines: a —unirradiated BeO; b —irradiated with an integral fluence of $2 \cdot 10^{21} \text{ n/cm}^2$. The intensity scale is not preserved.

Figure 2

Figure 3: Figure 2

Fig. 2. Change in the shape of the (002) BeO line at different degrees of irradiation: *a*—unirradiated specimen; *b, c, d*—specimens irradiated with different integral fluences $\sim 2 \div 6 \cdot 10^{20}$ n/cm².

the value $\Delta c/c = 2.7\%$, which agrees with the literature data on measurements of parameters on single crystals.

Figure 3 shows a Laue photograph from a powder particle of size $70 \times 60 \times 100 \mu$, which resulted from the crumbling of a BeO block after an integral fluence of $2 \cdot 10^{21}$ n/cm², taken with copper radiation. In this radiograph it is easy to detect reflections of two kinds: *a*—sharp ones, representing regular Laue reflections; the size of these spots corresponds to the size of the crystallite and to the geometrical conditions of the exposure; and *b*—strongly blurred reflections, the origin of which has not yet been definitively established. It is possible that the two kinds of reflections on the Laue photographs correspond to two crystalline lattices, which differ somewhat in the magnitude of the parameter *c* and are oriented differently relative to one another, having a common *c* axis.

It is still difficult to give a final interpretation of the results obtained. However, it may be assumed that the observed X-ray effects indicate, in the first stage of irradiation (up to $2 \cdot 10^{20}$ n/cm²), the accumulation of individual defects, which with further irradiation gather into complexes; in connection with this, some distortion of the BeO crystal structure occurs.

These ideas are in basic agreement with work ⁽⁶⁾, where an attempt was made to present a model of radiation damage in BeO.

Further development of the work is directed toward the interpretation of the observed effects of radiation damage in BeO.

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