BeO is reported (13, 14) to have a Mohs hardness of 9, which would correspond to a Knoop hardness of approximately 2000 $kg/mm^2$. It can be seen from our data that its true hardness is closer to 8 than 9. In view of the correlations obtained with bond distance, band gap, etc., it is felt that hardness reflects a measure of the bonding energy of the compounds.

The anisotropy of the hardness measurements for the wurtzite compounds is felt to be a true reflection of the differential bonding. Hardness values are lower on the $(10\bar{1}0)$ than on the basal plane where the hardness is isotropic. On the $(10\bar{1}0)$ surface the highest hardness parallels the (0001) face. The lower hardness parallels the prismatic cleavages (15-18).

The explanation presumably lies in the fact that basal cleavage, with the breaking of one bond per unit cell area, leaves the two halves oppositely charged, while breaking the same number of bonds along $(10\bar{1}0)$ and $(11\bar{2}0)$ leaves both halves neutral. In order to leave both cleaved basal planes neutral it would be necessary to break two bonds per unit cell.

The differential hardness on the (0001) and $(000\bar{1})$ as found on BeO and ZnO is at this time difficult to explain, but it is felt that either dislocation density or strain is responsible for the difference.

## Summary

The microhardness of BeO, ZnO, AlN, CdS, ZnS, and CdSe have been measured as a function of orientation and compared with the literature. Their hardness can be correlated with band gaps, bond distance, and melting point.

It is felt that the orientation dependence of the hardness can be explained by the crystal structure.

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## REFERENCES

1. H. Ott, *Z. Physik*, **22**, 201 (1924).
2. W. Zachariasen, *Z. physik. Chem.*, **119**, 201 (1926).
3. G. Jeffrey *et. al.*, *J. Chem. Phys.*, **25**, 1024 (1956).
4. D. K. Smith, H. W. Newkirk, and J. S. Kahn, *This Journal*, Being reviewed.
5. J. J. Gilman, Paper presented at American Ceramic Society Meeting, April 29, 1962, New York.
6. J. Westbrook and J. J. Gilman, G. E. Report 62-RL-2972M, March 1962.
7. V. M. Goldschmidt, *Norske Vod. Akad. i. Oslo Skr., Mat.—Nat. Kl.*, **8**, 102 (1926).
8. G. A. Wolff, L. Tolman, N. J. Field, and J. C. Clark, "Semiconductors and Phosphors," Interscience Publishers, Inc., New York (1958).
9. G. A. Wolff, Personal communication.
10. R. Bube, "Photoconductivity of Solids," John Wiley & Sons, Inc., New York (1960).
11. N. B. Hannay, "Semiconductors," Reinhold Publishing Corp., New York (1959).
12. G. A. Wolff, Private communication.
13. F. H. Norton, "Refractories," McGraw-Hill Book Co., Inc., New York (1949).
14. F. H. Norton, *J. Am. Ceram. Soc.*, **30**, 242 (1947).
15. J. D. Dana, "The Systems of Mineralogy," John Wiley & Sons, Inc., New York (1944).
16. L. Helmholtz, *J. Chem. Phys.*, **3**, 740 (1935).
17. C. F. Cline, V. D. Frechette, and J. S. Kahn, Abstract of paper presented at the British Ceramic Society Meeting on Mechanical Properties of Nonmetallic Crystals and Polycrystals, Hasting, England, October 1962.
18. G. A. Wolff and J. D. Broder, *Am. Mineral.*, **45**, 1230 (1960).