Strength of Moissanite

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Introduction

Despite the tremendous success achieved from using diamond anvil cells in all fields of high-pressure research, there has been a continuous effort to search for new anvil materials that are complementary to diamond but not limited by its cost, availability, and crystal size. In a recent report published in *Science*, Xu and Mao [1] showed that the hexagonal silicon carbide, moissanite, is an ideal material in this regard. It is believed that the use of moissanite anvil cells will open a new window for high-pressure studies that require large sample volumes and stable and accurate temperature measurements. To evaluate the applications of moissanite anvils to high-pressure and high-temperature research, one needs knowledge about moissanite's strength, which is a fundamental property for measuring resistance to plastic deformation. In particular, the temperature dependence of the yield strength will define limitations on industrial applications of moissanite if a high-temperature condition is desired and on the use of moissanite as anvil material for high-pressure experiments with external heating.

Methods and Materials

In this study, we use the principles outlined by Weidner et al. [2] to obtain information on stress and strength in the powder samples from x-ray diffraction signals. The full width at half-maximum (FWHM) differential strain for Gaussian distribution at elevated pressure and temperature is calculated by $\varepsilon = (1/E)[W_o(E)^2 - W_i(E)^2]^{1/2}$, where E = the x-ray photon energy, W_o = the observed peak width at a given experimental condition, and W_i = the instrumental contribution. By multiplying the differential strain by an appropriate aggregate Young's modulus (447 GPa for moissanite), one can convert the strain to stress, which is controlled by the strength of a material.

The strain measurements were performed on the powder moissanite sample by using a DIA-type cubic anvil apparatus [3] and a newly developed T-cup high-pressure system [4]. An energy-dispersive x-ray method was employed by using white radiation from the superconducting wiggler magnet at beamline X17B of the National Synchrotron Light Source and from the bending magnet at beamline 13-BM-D of the APS. In both experiments, NaCl was used as an internal pressure standard, and temperatures were measured by a W/Re25%-W/Re3% thermocouple.

Results

The yield strength of moissanite has been investigated at pressures up to 18.3 GPa and temperatures up to 1200°C (Fig. 1). At room temperature, the moissanite crystal behaves elastically with increasing pressure up to 13.7 GPa. At higher applied pressures, the sample is yielded. The yield strength of moissanite is determined to be 13.6 GPa or the equivalent to a maximum shear stress of 6.8 GPa. For comparison, the maximum shear stress that can be supported by moissanite in the shock state was found to be 7 GPa at an applied pressure of 21 GPa [5]. Upon heating moissanite at 18.3 GPa, significant stress relaxation is observed at temperatures above 400°C, and the yield strength of moissanite decreases rapidly from 12.8 GPa at 400°C to 4.2 GPa at 1200°C. For comparison, the yield strength of diamond was estimated to be 15 GPa

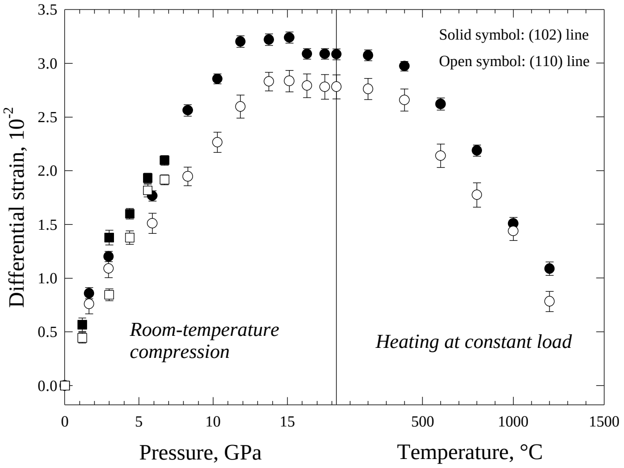

FIG. 1. Differential strain determined from the broadening of the (102) and (110) diffraction peaks of moissanite at various pressure and temperature conditions. Squares and circles correspond to the data from the DIA and T-cup experiments, respectively. The plotted error bars reflect the propagated errors in the peak width determinations for the (102) and (110) diffraction lines.

at 1200°C and 6 GPa at 1550°C [6]. As expected, moissanite is much weaker than diamond, even though the rate of thermally induced weakening in diamond is substantially greater than that in moissanite.

Discussion

The present results have implications on the development of the next generation of large-volume, high-pressure apparatus with moissanite as the anvil material [1]. The strength of moissanite is highly compromised at temperatures above 400°C. Above 1000°C, it becomes even weaker than tungsten carbide at ambient temperature (~6 GPa). Such behavior will place severe limitations on the use of moissanite as anvil material when external heating is desired for high-pressure and high-temperature experiments.

Acknowledgments

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