High Pressure-High Temperature Device for Making Diamond Materials

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This abstract describes a device for generating high static pressure in combination with high static temperature in a relatively large volume. One such high pressure-high temperature (HPHT) system has been installed in the Center for Nanomaterials Research at Rutgers University, New Jersey, and the other system is in our facility (Fig. 1). These systems were developed for a pressure range of 1-10 GPa, temperature range of 20-2,000°C, and volume range of 1 mm^3 – 1 cm^3. The devices are designed for high pressure sintering of micro- and nano-diamond powders. These units enable us to synthesize different diamond materials and study the transformation of carbon based materials into diamond. High pressure doped diamonds and new nanostructured carbon materials have been created with the help of the HPHT systems.

The present HPHT system consists of a hydraulic press, a high pressure apparatus with profiled anvils, plastic stone container, reaction cell with graphite ceramic heater, direct current power supply, and electronic equipment for measuring P,T-parameters. The system was developed with the support of a grant from the Dept. of Energy [1]. Additional funding from the National Science Foundation is supporting a new device that we call "supercell" [2-5], which is being developed for achieving 10-20 GPa pressure range, 2,000-5,000°C temperature range and a volume of 1 mm^3 – 1 cm^3. This project for generating very high pressures and temperature is underway in order to study carbon phase diagram, making large diamonds, and physical simulation of processes inside the Earth and other planets.

Generation of very high pressures in large volumes is becoming possible due to the development of profiled anvils with extremely tough but softer nanostructured bearing parts of WC/Co, extremely hard working parts of TiC, and prestressed supporting steel rings. Realistic mechanical and thermal calculations, and a special plastic container are needed to achieve this. The dependence of pressure on loading force (F) can be described by formula (1),

$$P = F \Big/ \left(S + \frac{F}{H_v} \right) \qquad (1)$$

where S is effective area of the anvil working part and H_v is Vickers hardness of the anvil working part. The dependence of generated pressure on loading force (if S=1 cm^2) is shown in Fig. 2 for hardened steel, WC/Co, WC, WC/TiC/Co, TiC and diamond faced anvils (in V_o ~ 1 cm^3 volume).

A better approximation is given by formula (2):

$$P = F \Big/ \left(a_o S - a_1 \sqrt{F} + \frac{a_2 F}{H_v} \right) \qquad (2)$$

where a_i are experimentally measured parameters with the help of known transitions in metals and compounds. The a_i depend on the shape of the cavity, properties of the plastic container, and properties of the anvil material.

The working volume depends on the value of maximum pressure that is needed to generate and the value of maximum force. The dependence of available working volume on available loading force and maximum needed pressure (if P_{max} = 1 GPa, 10 GPa, and 20 GPa) is depicted in Fig. 3.

Fig. 1 High Pressure-High Temperature (HPHT) system.

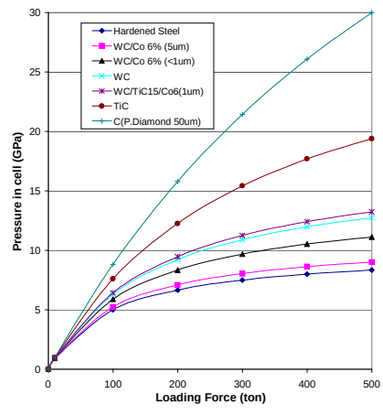

Fig. 2. Pressure generation in plastic stone between hard anvils.

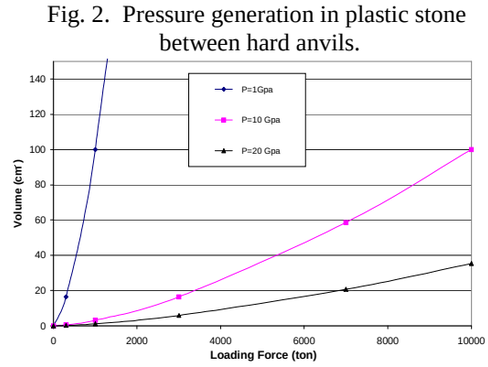

Fig. 3. Dependence of high pressure volume on available force.

Acknowledgments

The authors acknowledge support from the Dept. of Energy under grant #DE-FG02-96ER82154 in developing the HPHT device for making diamond materials. The project of building a new generation "Supercell" is currently supported by NSF grant #0060309.

References

1. O. Voronov, G. Tompa, R. Sadangi, B. Kear, C. Wilson, P. Yan, "Superhard Nanophase Cutter materials for Rock Drilling Applications," Report DMI-41018-Final, 23 June 2000, 96 pages.
2. P.W. Bridgman, Scient. Amer, Nov. 1955, p. 42.
3. H.T. Hall, U.S. Patent #2,941,248, "High Temperature-High Pressure Apparatus," 1960.
4. L.F. Vereshchagin et al., U.S. Patent #3,746,484, "Apparatus for Achieving High Pressure and High Temperature, 1960.
5. O.A. Voronov, U.S. Prov. Patent Appl. #60/226,318, "Supercell for Achieving High Static Pressure and Temperature in a Relatively Large Volume," 8/21/00.