Publ. Obs. Astron. Belgrade No. 44 (1993), 103–106

SOME POSSIBLE ASTROPHYSICAL APPLICATIONS OF DIAMOND ANVIL CELLS

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The pioneering experiments of Bridgman,in the early and middle parts of our century,have marked the beginning of the modern period of experimental high-pressure work (for a review of his work see Bridgman,1964).Bridgman used large volume presses which could contain large samples and in which the P - T gradients were diminished,but which had the disadvantages of a limited P - T range,no direct observation of the sample was possible,and were expensive to install and maintain in operating conditions.

A breaktrough in high pressure experimental techniques occured near the middle of this century (Lawson and Tang,1950; Jamieson et al,1959;Weir et al,1959) with the invention of the diamond anvil cell (DAC).The first DACs were built with the aim of performing high-pressure x-ray diffraction studies and infrared absorption measurements under high pressure.Later evolution.described in detail in the literature (such as Jayaraman,1983,1986; Williams and Jeanloz,1991;Angel et al,1992;Itie,1992), has converted the DAC into a versatile quantitative tool for physical research.

The basic principle of the DAC is extremely simple.A sample is placed between the flat paralel surfaces of two opposed diamond anvils,and it is subjected to pressure when the diamonds are pushed together by an external force.Variations in DAC types arise from different ways of generating the external force ,transmitting it to the diamonds and alining them.In order to achieve hydrostatic experimental conditions,a gasket is inserted between the diamonds.

The gasket is a thin small metal foil, with a hole containing the pressure transmitting medium and the sample in its center. Pressure is measured in the "ruby scale": the R lines of ruby (Al_2O_3 doped with Cr^{3+}) have a well known pressure shift. Accordingly, a small chip of ruby is placed in the hole in the gasket, and its fluorescence is excited by a laser or any other source of strong light. This scale is linear up to at least 30 GPa (Jayaraman, 1983); in its non-linear form, the ruby scale can be applied for pressure measurements up to 250 GPa (Ruoff, 1992a); at higher pressure only X-ray diffraction measurements can be performed. Experiments in DACs are complicated by the miniaturized scale: for example, the hole containing the sample and a chip of ruby has a diameter of only 200 μm, while the typical size of the samples is of the order of 40-50 μm. Experiments can be performed in the interval of temperatures between 4K and around 7000 K (Williams and Jeanloz, 1991).

What applications can DAC experiments have in astrophysics? It is a "fact of life" that no direct observation of planetary or satellite interior is possible. Some of the observable planetary parameters critically depend on the conditions prevealing in their interiors, and the only experimental method for investigating them is the use of DACs.

For example, the giant planets of the Solar System contain a large percentage of hydrogen, and the obvious question is how does it behave under extremely high pressure (of the order of hundreds of gigapascals, as in the center of Jupiter). Theory predicts that hydrogen becomes metallic at a pressure of 200-300 GPa (for example, Wigner and Huntington, 1935; Barbee et al, 1989; Ashcroft, 1989 and many other papers). Claims were recently made that metallization of hydrogen was detected in a DAC at a pressure of $P \cong 200$ GPa (Mao and Hemley, 1989), but they were later shown to be incorrect (Ruoff, Greene, Ghandehari and Xia, 1992). Accordingly, the existence of metallic hydrogen in deep interiors of the giant planets, and its possible consequences on the observable planetary parameters is still an unsettled question.

A closely related problem is the behaviour of ice under high pressure. A new high pressure, low temperature phase, called ice XII, has recently been discovered (Bizhigitov and Sirota, 1986). It is stable for temperatures between 90 and 250 K, and in the pressure interval 1200 - 2150 MPa. The preceeding phase, ice XI, becomes metallic at P = 1.76 TPa (Hama et.al, 1990). Such data are relevant for modellization (and interpretation of observations) of the giant planets and their satellites: to the author's knowledge, they have not been widely used.

What about the interior of the Earth? Its composition is one of the most important planetological problems (Knittle and Jeanloz, 1991b), but it is generally assumed that it consists of a metallic core surrounded by a rocky crust (Jeanloz, 1990). Experiments in DACs have given valuable indications about the conditions in its deep interior, such as the central temperature (Williams, Jeanloz, Bass et al, 1987), the temperature at the core-mantle boundary (Knittle and Jeanloz, 1991b), or the possibility of chemical reactions between the silicates and liquid iron (Knittle and Jeanloz, 1991a). An analysis of melting of iron under high pressure (Čelebonović, 1993a) has given indications about the changes of the Gruneisen parameter of iron under pressure, which is an example of a planetologically motivated result in solid-state physics. Numerous other examples of DAC experiments giving planetologically interesting information can be found in the literature (such as Jeanloz, 1989, 1990; Williams and Jeanloz, 1991).

Instead of a conclusion, a preliminary information: some work concerning the high pressure behaviour of planetologically interesting materials is going on in the Institute of Physics. Those interested are invited to contact the author.

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