High Temperature Research

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1. Introduction

The BL38 B1 is a bending magnet beam line. This beam line has no monochrometers and white x-rays will be supplied to the experimental stations. Two scientific subgroups, high pressure mineral physics group and high temperature group, are planning to build their experimental hutches on this beamline. Continuous white x-rays (10-200 keV) will be used for the experiments.

2. High Pressure Mineral Physics

2.1 Research Subjects

The aim of the high pressure mineral physics group is to reveal the origin, evolution and present state of the internal structure of the Earth and other planets. For this purpose, various properties of planetary materials, such as iron, silicates, hydrogen and helium, will be investigated under high pressure and high temperature. In particular, x-ray diffraction study under high pressure is a main subject in this beamline. The extreme pressure and temperature conditions corresponding to those of planetary interiors can be obtained with a multi-anvil type high pressure apparatus, which will be installed on this beam line.

Various kinds of high pressure minerals constitute the Earth's mantle, and metallic iron with substantial amounts of the lightening elements (e.g., H, O, S, Si etc.) is thought to constitute the Earth's core. In recent years, seismic study has progressively revealed detailed structure of the deep interior of the Earth. In order to interpret such new information and to clarify chemical composition, mineralogical constitution, and thermal state of the Earth's interior, we need quality data on the physical properties of these materials. Different kinds of experiments on the candidate materials, such as $(Mg,Fe)SiO_3$, $(Mg,Fe)_2SiO_4$, and the iron alloy, will be carried out using x-ray diffraction and radiography techniques. These include: 1) structure of high pressure phases, 2) phase diagrams, 3) equations of state, 4)kinetic properties of the phase transitions, and 5) rheological and fracture properties.

The multi-anvil press is a suitable facility for the study of the Earth's interior. It covers pressure regions to those found in the upper part of lower mantle, and its large sample volume cavity makes it possible to control the pressure environment (hydrostatic or differential stress conditions) and to realize uniform temperature.

2.2 Experimental Facilities

The experimental station for the high pressure mineral physics will occupy the upstream hutch in this beamline. A large volume multi-anvil type high pressure apparatus is installed in this hutch. This high pressure apparatus has a 1500 ton ram-force uniaxial press with a cubic anvil type guide block, and is operated in the two-stage mode (so called 6-8 system) to reach the desired P-T conditions. Either the tungsten carbide alloys or the polycrystalline sintered diamonds will be used for the second stage anvil. This system has a capability of generating pressures up to 40 GPa and a temperature of 3000 K using a solid pressure medium. For the x-ray experiments, two single-axis goniometers (vertical and horizontal directions) are equipped by the high pressure press. The press is mounted on an x-y-z translation stage with a rotation axis to align the beam with the sample. The

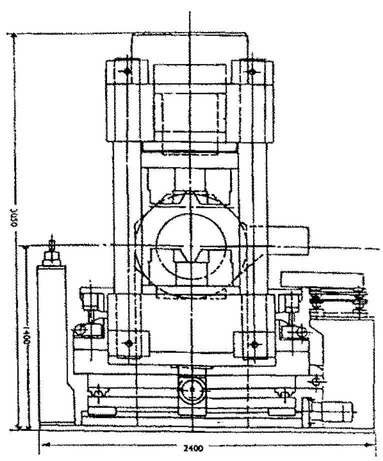

Fig. 1.
The multi-anvil high pressure apparatus.

divergence slit for the incident beam is mounted separately on a y-z positioning stage in front of the press. The vertical and horizontal goniometers are mounted on y-z and x-y-z positioning stage, respectively. The Ge solid state detector is used for the energy dispersive x-ray diffraction experiments.

3. High Temperature

3.1 Research Subjects

The aim of high temperature group is to investigate the structural properties of disordered materials under high temperature. By changing temperature and pressure, we can realize supercritical fluids and high density plasma with changing density continuously. The density can be changed continuously also by using liquid, because alloys are usually miscible in any concentration in liquid state. These changes in the electronic density affect the interaction between atoms, and cause the structural change. In order to study these density changes as well as its fluctuations and cluster formations, we are planning to construct the station for measurements of x-ray diffraction at high temperature and high pressure.

The first topic is the structural studies for expanded fluid metals and semiconductors. When liquid metals are heated and pressure is applied to prevent boiling, significant density decreases can be achieved. When temperature is elevated at low pressure, the first-order phase transition from liquid to gas occurs accompanied by a large volume change. At higher pressure, the liquid can be heated to much higher temperature and lower density. The volume change on vaporization decreases with increasing pressure, and disappears at the critical point. At the pressure higher than this critical pressure, the volume of expanded fluid can be changed continuously in a wide range by heating. The structure of these expanded fluids, such as Hg and Se, will be studied in a wide density range by the x-ray diffraction measurements and the small-angle x-ray scattering.

The second target is the partial structures in multi-component system. Many disordered materials used for applications, such as amorphous alloys, oxide glasses and amorphous semiconductors, consist of more than two kinds of atoms. To understand the properties of multi-component system, the information on the partial structure factors is needed. A full set of partial structure factors may provide us details of a local structure in a multi-component disordered system. This would enable us to understand some relations between local atomic structures and physical and chemical properties in disorder materials.

3.2 Experimental Facilities

The high temperature experimental station will be built in the downstream hutch of this beamline. This station is composed of a high pressure and high temperature generation system and an energy dispersive x-ray diffractometer. The former system includes a compressor, a high pressure vessel, a thermocontroller, and a chiller. Since helium high pressure gas is used as pressure medium, all these facilities will be placed in small rooms surrounded by the protection wall built inside the hutch. The pressurized gas is transferred from the compressor to the vessel through a high pressure tube. This high pressure vessel permits x-ray diffraction measurements at high temperature and pressure up to 1650°C and 2000kg/cm^2. The vessel has Be windows for the incident and scattered x-ray beam. The high pressure vessel is mounted on a horizontal goniometer which is fixed on an x-y-alfa stage. The goniometer and the stage are controlled using a personal computer from outside of the hutch. White x-ray beam collimated with a incident slit is irradiated to a supercritical fluid and the intensity of scattered x-rays is measured with a solid state detector.

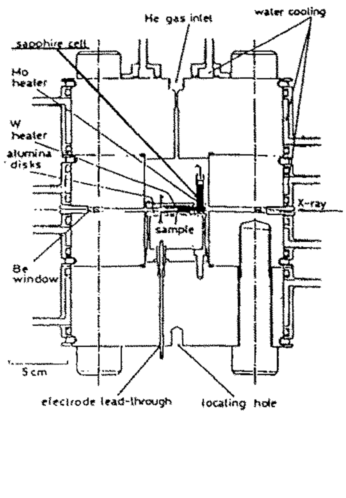

Fig.2.
Cross section of the high pressure gas vessel.