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Melting temperature measurements of water using a laser-heated diamond anvil cell technique with CO_2 laser

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The phase relations and physical properties of water at high pressures and temperatures are important to physical, geophysical, and planetary problems. For example, recent molecular dynamics calculations suggest that water is superionic at high densities relevant to planets such as Uranus and Neptune, and this predicted property plays a key role in dynamo models to explain the unusual non-dipolar magnetic field structure of these planets. The advances in combining techniques such as synchrotron x-ray diffraction or in situ optical Raman spectroscopy with diamond anvil cell (DAC) technologies allow us to measure the melting temperature of water to within a few percent for pressures up to 35 GPa. However, at pressures above 35 GPa, recently reported values of melting temperature exhibit significant differences with each other. This discrepancy should be caused by a chemical reaction occurred between the metal absorber contained in the DAC and the dissociated water. By using CO_2 laser for sample heating, the metal is not necessary because water has significant absorption in the wavelength range of CO_2 laser (10.6 micron). We report the melting temperature of water in a diamond anvil cell more than 35 GPa using CO_2 laser heating system.

We performed the experiments using a DAC with diamonds having flats of 300 micron diameter. Third distilled H_2O was loaded into a ˜100 micron diameter and ˜50 micron thick sample chamber in a DAC. A rhenium gasket was used to contain the sample. The samples were first compressed to a required pressure at room temperature and then heated by two CO_2 lasers with a both-sided heating technique reducing the axial temperature gradient in the sample. The incident angle of radiation of the CO_2 lasers (Synrad 100 W) is about 20 degree. The laser beams were focused by ZnSe lens onto the sample in a DAC. The heated area, which corresponds to about ˜30 micron, is imaged from both sides of sample on the slit of the entrance of the spectrometer and the two charge coupled device (CCD) detectors, respectively. The temperature was measured by the spectroradiometric method. The uncertainty in temperature within the 30 micron area was less than approximately 7 % stemming from radial temperature gradients.

Melting was determined by plotting the laser power / sample temperature function and looking for the thermal anomaly associated with melting. We found a temperature plateau arising from the melting of water at each pressure. This temperature was determined as the melting point. Another heating experiment of water including a small amount of Ir powder ($<$10 micron) was performed for cross-check of the melting temperature determined from the relation between the power and the temperature. The temperature when the powder moves was in good agreement with that of the plateau at each pressure. This fact supports that the temperature of the plateau corresponds to the melting point.

The melting temperatures determined in this experiment are much lower than those of the planetary isentropes of Neptune and Uranus. Therefore, at least, solid water might not exist in the interiors of Uranus and Neptune at 100 GPa.

Keywords: water, laser-heated DAC technique, high pressure