Phase Changes of Solid Methane under High Pressure and High Temperature, their Implications in Mantle of Icy Planets

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High pressure and high temperature experiments of solid methane were performed in the pressure range of 10 to 81 GPa, the temperature range of 1000 to 3000 K, using diamond-anvil cell, CO_2 or Nd:YAG-laser. X-ray diffractmetry and Raman spectroscopy were performed after the samples were cooled. In results, five different regions were distinguished depending on the temperature distribution under wide pressure range. In the lowest temperature region (below 1100K, Region I), the solid methane were kept in spite of heating. Above 1200K, solid methane started melting and polymerization. The sample heated at temperatures between 1200 and 1600K (Region II) became amorphous after cooling indicated by XRD and Raman spectroscopy. Differences in refractive index from surrounding solid methane or Region I were clearly observed during and after heating. Above 1800K (Region III), ethane molecules got increasing. After cooling, this sample crystallized into Van der Waals compounds consisting of methane and ethane molecules reported just recently. Above 2200K (Region IV), existence of more polymerized hydrocarbon was indicated by XRD pattern of the cooled sample. Although new broad spot were observed in this XRD pattern, these peaks cannot be indexed as anything supposed to be produced in sample room, except for more polymerized hydrocarbon. The color of sample heated approximately 3000 K (Region V) turned into black. XRD pattern of the cooled sample was indexed as diamond.

According to theoretical studies, the pressure and temperature conditions of the upper part of middle ice layer in Neptune and Uranus were calculated to be approximately 10GPa and 2000K. On the basis of the experimental results, this part might be molten, and methane and polymerized hydrocarbon might exist in this part. Their atmosphere enriched methane and small amount of polymerized hydrocarbon might be kept by supplying various hydrocarbons from their ice layer. In deeper part of ice layer, more polymerized hydrocarbon and diamond might exist.