THE RHEOLOGICAL PROPERTIES OF POLYCRYSTALLINE NITROGEN AND METHANE: IMPRICATIONS FOR TECTONIC PROCESS ON TRITON. Y. Yamashita[1] , M. Arakawa[1], and M. Kato[2], [1]Nagoya University (Furo-cho, Chikusa, Nagoya, Aichi 4648601, Japan. E-mail: arak@eps.nagoya-u.ac.jp), and [2]Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Sagamihara, Kanagawa 2298510, Japan. E-mail: kato@planeta.sci.isas.jaxa.jp)

Introduction: Solid methane on the surface of Pluto has been observed by the infrared spectroscopy on the ground [1]. With the technical improvement of the observation, solid methane and solid nitrogen were discovered on the surface of Triton[2]. The space probe Voyager, encountered Neptunian system in 1989, exposed the characteristic surface structure of Triton [3]. The formation of this structure might not be clarified without any knowledges of the physical properties of non-water ice such as solid nitrogen and solid methane; they are main compositions of the surface. In recent years, solid carbon monoxide and solid carbon dioxide on the surface of Triton [4] and solid nitrogen and solid carbon monoxide on the surface of Pluto [5] were confirmed by ground-based observation. Therefore, non-water ices could be the main compositions to construct the surface crust of Kuiper Belt Objects [6][7].

It is necessary to know the viscosity of non-water ices to investigate the surface geology. Impact craters are very rare because the relaxation time of the crater could be very short. In contrast there is a very famous geological structure of cantaloupe terrain on Triton. This structure means that the nitrogen crust must have an enough mechanical strength to support the shape against the gravitational body force. In spite of the importance, the measurements of viscosity and strength of non-water ices have not been conducted experimentally.

In our previous study, the sound velocities at 64 - 90 K were measured by using low-porosity solid methane and solid carbon dioxide, and the viscosity of solid methane at 77 K was estimated [8]. With improvement of the experimental system, the sound velocities of solid methane and solid nitrogen from 5 K to melting points were measured and further more the viscosity and strength of solid nitrogen was measured in this study.

Deformation Test Setting: The schematic cross section of the low temperature uniaxial deformation system is shown in Fig 1. The cryostat system with double dewars was the same as that used for the sound velocity measurement, but the sample cell was customized for the deformation test. The sample cell is a hollow glass column with height of 15 mm and inner diameter of 10 mm. The samples were grown slowly in a sample cell after the cell inside was evacuated at 0.1 Torr with a vacuum pump. The cooling rate of sample

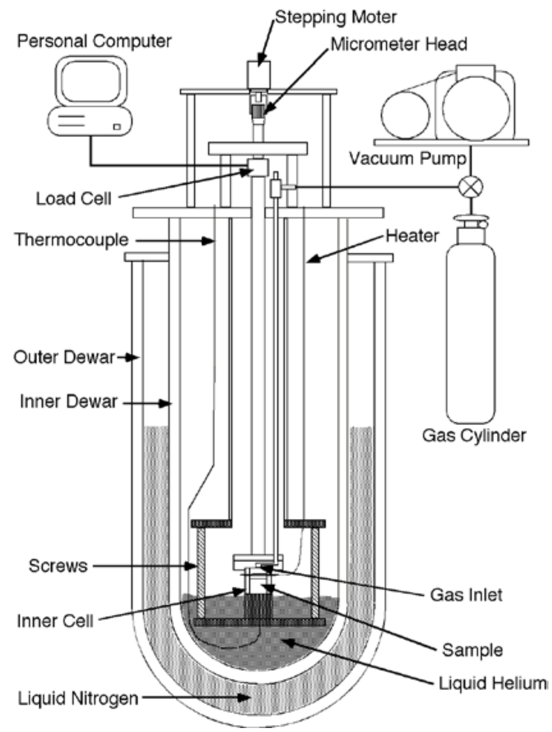

Fig.1 Schematic Diagram of Experimental Setting

solidification is controlled below 1 K/min. The sample of solid nitrogen and methane can be grown with very low porosity and cooled from melting point down to 5 K without producing any cracks inside, respectively. The sample shape was cylinder with 10 mm in the diameter and 6 - 7 mm in the height. Deformation tests were carried out after the sample cell was extracted from samples. The temperature difference at the upper and lower ends of the sample is within 1 K. The temperature conditions of solid nitrogen and methane were 5 - 56 K and 5 - 77 K, respectively, and those of strain rates were 1×10^{-4} - 1×10^{-2} s^{-1}. The displacement was controlled by rotation of a stepping-motor. Stress was measured by a load cell and the data were collected at every 0.1 second in micro-computer through a 12 bit A/D converter. The deformation of samples continued until the stain was about 50 %. The sample deformation in all of the experiments was recorded by a video camera.

Test Results: The sample before compression looked transparently without pores and cracks. As the strain increased progressively, the central part of the sample expanded radially like a barrel without any cracks in it. This type of the deformation is ductile flow. This ductile flow was usually observed at the higher temperature range.

Typical stress-strain curves showing the ductile flow and the brittle failure of solid methane are shown in Fig. 2. This means that even at the same strain-rate the deformation type of solid methane changes from ductile to brittle with the decrease of temperature.

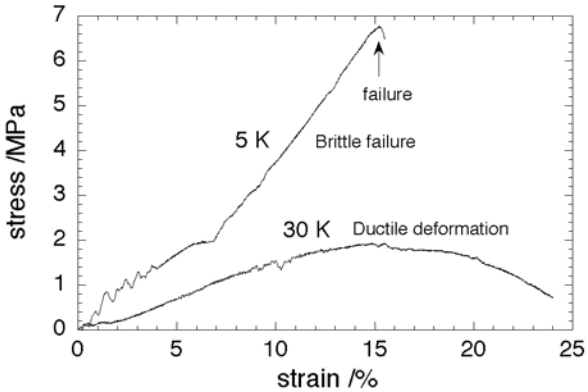

Fig.2. Deformation of Solid Methan

Several stress-strain curves of solid nitrogen samples under the same temperature condition of 30 K are shown in Fig. 2. It indicates that the sample shows ductile flow. At larger strain-rates the profiles do not show yielding but they suddenly drop to have a sharp peak, so it means that the sample changes the deformation type from ductile flow to brittle failure with the increase of strain-rate. The maximum stress increases with the increase of strain-rate from 4 MPa to 7 MPa, it means that the strength of solid nitrogen becomes larger with the increase of strain-rate irrespective of deformation type.

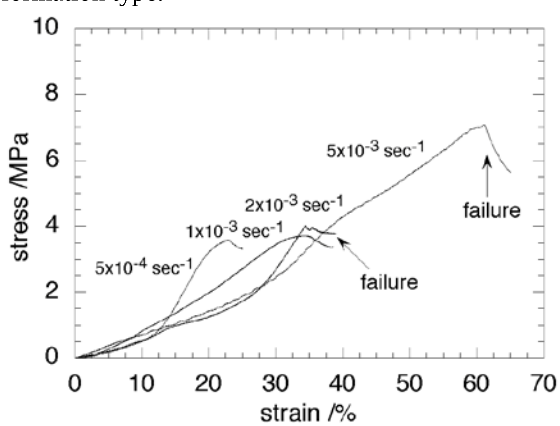

Fig.3 Deformation of Solid Nitrogen at 30 K

Discussions: Images taken by Voyager 2 showed that there were few craters, which kept the original shape without relaxation, on the surface of Triton, and the largest crater was less than 25 km, thus we can expect that Triton is still active satellite and the surface is always renewed. However, the surface temperature of Triton is very low about 40 K so that water ice, which is the main component to construct icy satellites, is too viscous to flow on the surface. It means that impact craters formed on the water ice surface are not relaxed immediately to renew the surface of Triton. The undulation of the surface such as a terrain named as cantaloupe, which is a famous structure on Triton, is an order of several kilometers. This amplitude of the undulation could be limited by the material strength of the crust so that its strength to support the undulation is estimated to be about several MPa [9]. It is well known by astronomical observation that Triton's Surface is composed of solid nitrogen and solid methane but we cannot specify the subsurface material constructing the undulation: water-ice could be another important composition constructing the subsurface, so in order to investigate the subsurface materials to support the cantaloupe structure we are necessary to estimate viscosities of these candidate materials for the subsurface material.

In order to explain the existence of small fresh craters about several km on Triton's surface, we need to assume the hard subsurface, for example, composed of water ice to sustain the impact crater profile. This assumption could be confirmed by analyzing the thickness of the surface layer composed of solid nitrogen and solid methane, and they were supposed to be less than the depth of the minimum crater observed on Triton's surface: the depth was estimated to be about several 100 m [10] because the minimum crater size observed was about several km and the depth to diameter ratio formed on Triton was determined to be about 0.1. We suggest that it might be possible that the upper part of Triton's surface consists of two layers: the outer surface layer is composed of solid nitrogen or solid methane with the thickness less than several 100 m, and the subsurface is composed of water ice.

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