# 4. Basic, Applied, and Innovative Research

As an inter-university research institute, NIFS activates collaborations with researchers in universities as well as conducting world-wide top level researches. The collaboration programs in basic, applied, and innovative research support research projects motivated by collaboration researchers in universities. It is also important to establish the academic research base for various scientific fields related to fusion science and to maintain a powerful scientific community to support the research. Programmatic and financial support to researchers in universities who work for small projects are important. As an inter-university research institute in fusion science, NIFS performs such an important role and the programs in basic, applied, and innovative research are prepared for this purpose.

For basic plasma science, NIFS operates several experimental devices and offers opportunities to utilize them in the collaboration program for university researchers. A middle-size plasma experimental device HYPER-I is prepared for basic plasma research. The compact electron beam ion trap (CoBIT) for spectroscopic study of highly charged ions, atmospheric-pressure plasma jet devices for basic study on plasma applications, and other equipment are operated for collaborations.

(I. Murakami)

## Development of thermal conductivity in warm dense matter using pulsed-power discharge

A warm dense matter (WDM) is the intermediate state of matter, which is neither solid nor plasma. To understand the relation between solid state and plasma physics, a theoretical description of WDM is one challenge. Since the WDM has high pressure and dense matter state, we should develop how to observe the properties of WDM with well-defined state. To observe the thermal conductivity of a WDM sample, we developed a laser-induced fluorescence method to observe the thermal conductivity of tungsten WDM confined within a ruby capillary. We determined the density and temperature of the plasma generated by an isochoric heating device using a pulsed-power discharge. The density and the temperature were determined by the initial diameter of the tungsten wire, and were obtained by spectroscopic measurements, respectively. The temperature of the ruby capillary was obtained from its fluorescence intensity, which depends on the temperature of the outer wall. The experimentally obtained thermal conductivity is approximately 30 W/K m. We succeed that the thermal conductivity of WDM states is directly evaluated using the proposed method [1].

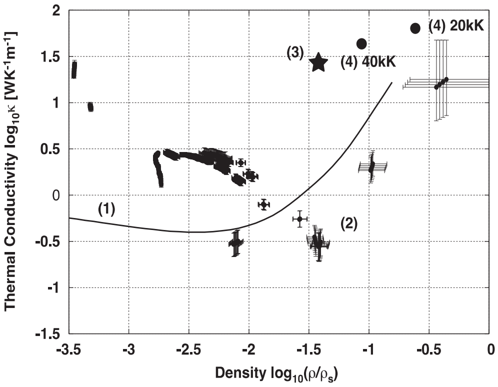

Fig. 1 Thermal conductivity of tungsten plasma as function of density at 10,000 K. (1) The solid line indicates the thermal conductivity given by the Kuhlbrodt-Holst-Redmer model from COMPTRA04. (2) The data points with error bars show semi-empirical estimates obtained using the Wiedemann-Franz law. (3) The star point plots the results obtained in the present study. (4) The circle point plots semi-empirical estimates obtained using the Wiedermann-Franz law with Rakhuk's results. Cited from [1].

(K. Takahashi and T. Sasaki, Nagaoka Univ. Tech.)

## Development of a polarization-modulation spectroscopy system for helium atom emission lines

The deviation of the electron velocity distribution (EVD) from isotropic Maxwellian is seen in various interesting plasma phenomena. For a better understanding of these phenomena and detailed comparisons between experiments and kinetic simulations, it is necessary to develop a method that can measure the three-dimensional EVD. As a possible method, we focus on the polarization of atomic emission lines. When the EVD shape becomes anisotropic, the emission lines are slightly polarized. The intensity and polarization degree for a given EVD vary with the type of transition, thus, the EVD shape can be deduced by measuring these quantities of multiple emission lines. We have developed a polarization-modulation spectroscopy system to measure full Stokes parameters of visible emission lines and applied the system to a helium ECR plasma (Fig. 2) [2].

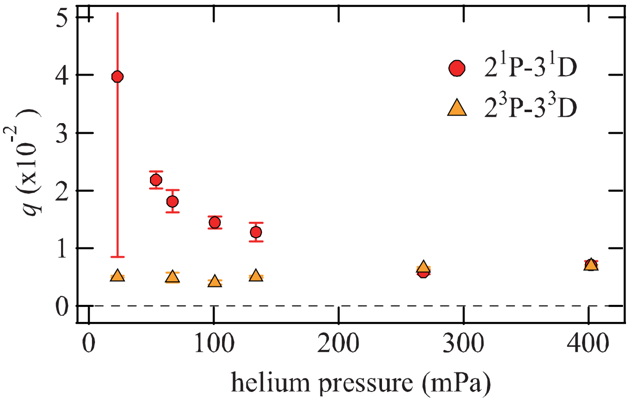

Fig. 2 Helium pressure dependence of a normalized Stokes parameter $q$ (corresponding to the linear polarization degree in the direction perpendicular to the magnetic field) for two types of helium atom emission line.

(T. Shikama, Kyoto Univ.)

## Improving biocompatibility of titanium alloy by atmospheric-pressure plasma nitriding

Several studies reported that the biocompatibility of titanium alloys can be improved by doping nitrogen atoms into the titanium surface. Our research group has developed the simplest technology of nitrogen doping with atmospheric-pressure plasmas, where no vacuum equipment is necessary although conventional plasma technology requires it. We recently achieved nitrogen doping to titanium surface by using our original atmospheric-pressure plasma nitriding with the pulsed-arc plasma jet [3]. In this article, we report the newest results on biocompatibility of titanium alloy into which nitrogen atoms have been doped by the plasma-jet nitriding. As shown in Fig. 3, the nitrided (left, golden color due to TiN surface) and the untreated samples (right, original gray color) are immersed into the simulated body fluid at 37°C for 10 days. Here, both of the samples have lost metallic luster owing to the formation of calcium phosphate layer. As a result of thickness comparison of the formed layer, we have demonstrated that the formation ability of the calcium phosphate on the nitrided sample outperforms that on the untreated sample [4]. This indicates that nitrogen doping by our method can upgrade hard-tissue compatibility of titanium alloy.

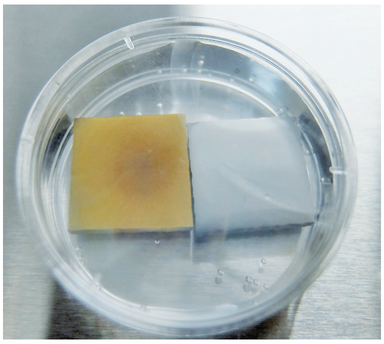

Fig. 3 Plasma-nitrided (left) and untreated (right) titanium immersed in simulated body fluid.

(R. Ichiki, Oita University)

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