NASA LAW, October 25-28, 2010, Gatlinburg

Laboratory Experiments of Solar Wind Charge Exchange with TMU-ECRIS and TES Micro-calorimeter

H. Akamatsu[1], T. Enoki, K. Henmi, Y. Ishisaki, Y. Ezoe, T. Ohashi, T. Kanda, T. Ishida, H. Tanuma

Department of Physics, Tokyo Metropolitan University, Hachioji, Tokyo, 192-0397, Japan

h_aka@phys.se.tmu.ac.jp

H. Ohashi

Institute for Laser Science, The University of Electro-Communications 1-5-1 Chofugaoka, Chofu-shi, Tokyo 182-8585, Japan

K. Shinozaki

Aerospace Research and Development Directorate, JAXA, Tsukuba, Ibaraki 305-8505, Japan

K. Mitsuda

Institute of Space and Astronautical Science, JAXA, Sagamihara, Kanagawa 252-5210, Japan

ABSTRACT

We are conducting a laboratory experiment to reveal the mechanism of Solar Wind Charge eXchange (SWCX) occurring in space. We employ a high resolution X-ray spectrometer system contained TES (Transition Edge Sensor) X-ray micro-calorimeters, and ECRIS (Electron Cyclotron Resonance Ion Source). Here, we report brief description of this experiment and its current status.

1. Introduction

In X-ray astronomy, it is still a question how diffuse soft X-ray emission shows time variations in a few days (Snowden et al. 1994). A possibility has been proposed that the emission is caused by charge exchange process between the solar wind ion and the interplanetary neutral matter.

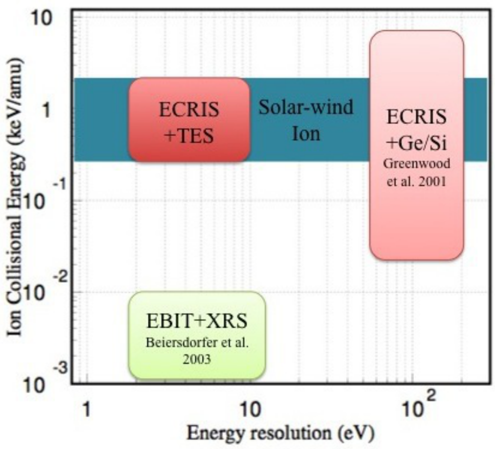

Fig. 1.— The current state of laboratory experiment for SWCX study. The energy of solar wind is around 1 keV. Our target area and previous studies related with SWCX are shown (Greenwood et al. 2001; Beiersdorfer et al. 2003).

Charge exchange process is an interaction between a highly ionized ion (A^{q+}) and a neutral atom (B). An electron is transferred from atom to ion, and goes into a highly excited level. When the electron make transitions to lower levels, the ion produce photon with the energy corresponding to the level difference. However, it is difficult to identify that this emission is truly generated by charge exchange process due to the spectral resolution of current X-ray astronomy satellites($\sim$ FWHM 100 eV).

For proper modeling of X-ray emission from SWCX, we need reliable data about line distribution and cross section of this process. But, there are few data with a few eV resolution under similar condition as the SWCX, regarding collisional energy (0.6-3.0 keV/amu:Fig1) (Greenwood et al. 2001; Beiersdorfer et al. 2003) . To separate individual emission lines of the charge exchange process, the high energy resolution measurement under SWCX condition is strongly required.

2. Our approach

We investigate charge exchange mechanism between solar-wind ion and neutral matter using high resolution TES X-ray micro-calorimeters and TMU-ECRIS(Fig.1). X-ray micro-

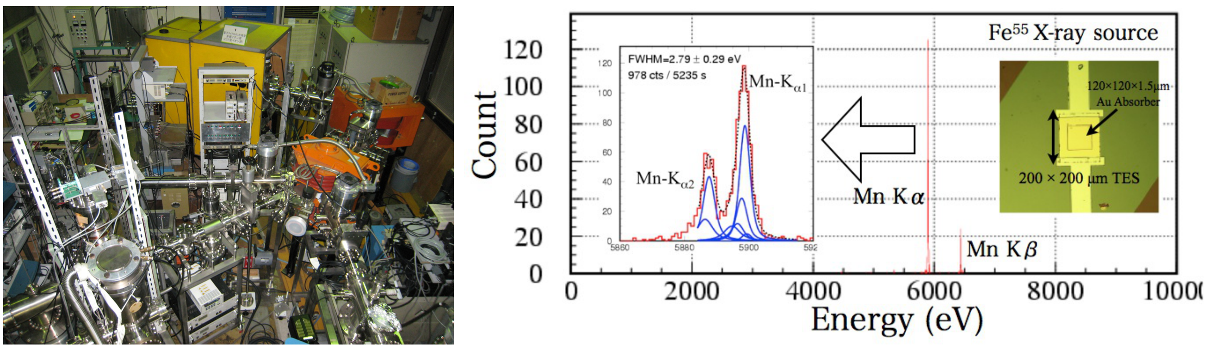

Fig. 2.— Our experimental set up Left: Ion collision facility with TMU-ECRIS. Right: Photo of our TES X-ray micro-calorimeter and energy spectrum of Fe^{55} X-ray source.

calorimeter is an X-ray detector that absorbs X-ray energy with the absorber, and produces signals when TES temperature rise. Micro-calorimeter shows excellent performance at an extremely low temperature below 100 mK. Energy resolution is given by $\Delta E \sim 2.35\sqrt{\frac{k_B T^2 C}{\alpha}}$. Where, k_B is Boltzmann constant, T is a temperature at working point of micro-calorimeter, C is a heat capacity of micro-calorimeter, and α is a temperature sensitivity of thermometer.

TES (Transition Edge Sensor) is a high sensitivity thermometer that works at transition edge of superconductor. TES calorimeters can achieve the energy resolution of 1 eV. Our group produced TES micro-calorimeters through in-house processes, and the sensor show good energy resolution of ΔE=2.8 eV @ 5.9 keV(Akamatsu et al. 2009).

Highly charged ions are produced in the 14.25 GHz electron-cyclotron resonance ion source at Tokyo Metropolitan University (**?**). The ion were extracted with electronic potential of several energy, and selected by a 110° double-focusing dipole magnet, and directed into a collision chamber where the ion intersected an effusive beam of target gas ejected from a micro capillary plate.

Our system (TES micro-calorimeter+ECRIS) will simulate the SWCX process and will measure X-ray with good energy resolution. Then, we can obtain a good laboratory data to understand the SWCX process.

3. Resent result

We measured X-rays from the collision of O^{7+} and O^{8+} ions with neutral He or Hydrogen molecule using a window-less Si(Li) detector. The detector shows an energy resolution of 107 eV @ 1 keV (Kanda et al.). As shown in the Fig. 3, we confirmed emission lines from 2p, 3p, and 4p to 1s transitions of O^{7+}. We analyzed the spectrum by fixing the peak energy of each line using the NIST database and the energy resolution to be 107 eV. The results indicate some difference from the previous work (Greenwood et al. 2001), in point of the intensity ratio of the lines. This might be caused by the correction of X-ray transmission (Tanuma et al. in prep) of the detector windows. To confirm this effect, a new high-resolution measurement will be important.

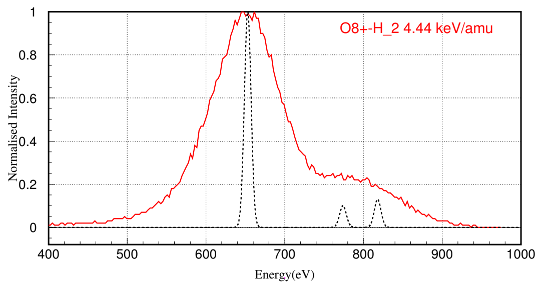

Fig. 3.— Preliminary result obtained by window-less Si(Li) detector. Black dot line show simulation that measured TES calorimeter (ΔE=10 eV).

4. Future prospect

Because the extremely low temperature is necessary for TES, we are developing a double stage Adiabatic Demagnetization refrigerator (dADR). dADR is a quite compact and can be carried to outside experiments. We could cool the double stage ADR down to about 100 mK, and holding time was 2 hours. In parallel with the test with the Si(Li) detector, we are preparing the TES calorimeter and dADR system. For the first step, evaluation of the TES calorimeter installed in the DADR is in progress. We plan to combine dADR system and ECRIS and measure emission lines from SWCX by the next summer.

This work is supported by KAKENHI 21246017, Grant-in-Aid for Scientific Research of JSPS. H.A supported by Grant-in-Aid for JSPS Fellows (22·1582) and the MEXT program “Support Program for Improving Graduate School Education”.

REFERENCES

Snowden, S. L. McCammon, D. Burrows, D. N. & Mendenhall, J. A. 1994, ApJ, 424, 714

Greenwood, J. B. Williams, I. D. Smith, S. J. & Chutjian A. 2001, Physica Scripta Volume T, 92, 150

Beiersdorfer P., et al. 2003, Science, 300, 1558

H. Tanuma et al., J. Chin. Chem. Soc., 48 389 (2001).

Akamatsu H. et al. 2009, American Institute of Physics Conference Series, 1185, 195

Kanda T. et al. 2010, HCI Conference, submitted

Tanuma H., et al. in preparation.
