Present Status and Future Plans of the SR Center in Ritsumeikan University

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Abstract. The SR center has been actively used in Ritsumeikan University for synchrotron radiation basic researches, education and training of graduate students and industrial applications for more than ten years. Present status of the storage ring and some recent activities are introduced. Future prospects are also addressed.

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INTRODUCTION

The world smallest storage ring with a super conducting magnet was developed by Sumitomo Heavy Industry Co. in 1991. Ritsumeikan University installed this storage ring as a symbol of the new campus, "Biwako-Kusatsu" in 1996. This was the first synchrotron radiation facility established in a university in Japan. Since then, the SR center was utilized for synchrotron radiation researches, especially for industrial applications. 10^{th} year anniversary was celebrated last year and we are now in the new phase of the center.

PRENSENT STATUS

The storage ring named, "AURORA" is a unique ring designed for X-ray lithography. It is so compact and no space for any additional attachment in the ring that we cannot upgrade the machine any more. In a sense, it is an established machine and has kept running more than 10 years without any serious trouble. The specification of the storage ring "AURORA" is listed in Table 1.

TABLE 1. Specification of "AURORA"

Ring energy	575 MeV
Ring current (Max.)	300 mA
Circumference	3.14 m
Harmonic Number	2
Critical wavelength	1.5 nm
Lifetime	5 hours
Natural emittance	1.6 μm rad
Operation time	From 9:30 to 20.30

Registered users in 2006 are 296 in total, in which 38 % are from outside. Among the outside users, 50 % are from industries. This is a significantly different situation from other facilities in Japan and demonstrates how the SR center put the weight on industrial applications. There are 14 beamlines operated in the center, which are roughly divided to 4 categories; XAFS, PES, Imaging and LIGA. Details are listed in Table 2. In the period of 2002-2006, the center has been approved by MEXT as one of the facilities to support nanotechnology experiments and accepted about 40 proposals/year related to nanotechnology.

TABLE 1. Details of the Beamlines

Beamport	Experiments
BL-1	X-ray diffraction/scattering (2 –10 keV)
BL-2	Ultra-soft X-ray spectroscopy (30-200 eV)
BL-3	XAFS (2-10 keV)
BL-4	XAFS (3-10 keV)
BL-5	LIGA exposure
BL-6	LIGA exposure
BL-7	2D PES (10-270 eV)
BL-8	PES (7-700 eV) and MEIS (120 keV)
BL-10	Soft X-ray XAFS (1.2-4.0 keV)
BL-11	Optics characterization (50 – 1500 eV)
BL-12	Soft X-ray microscopy (360 – 770 eV)
BL-13	SR micro-lithography
BL-14	SR ablation
BL-15	SR micro-lithography

SOME TYPICAL OUTPUTS

(1) One dimensional surface states on a stepped metal surface

By slanted cutting of a Ni(111) single crystal, we can obtain the Ni(332) stepped surface, as shown in Fig. 1. Angle resolved photoemission spectra (ARPES) at the photon energy of 10 eV give band dispersions of the valence bands. A series of the spectra in the left figure are those obtained by angle scan perpendicular to the stepped line, while those in the right figure are by angle scan along the stepped line. The peak at the threshold can be attributed to the surface state mainly come from stepped atoms. This is confirmed by gas exposure, which reduce the feature. Interestingly, we can find distinct band dispersion in the right figure, but not in the left figure. This result indicates that strong interaction occurs along the stepped atoms, but not perpendicular to the stepped line. Even though the sample is metal, stepped atoms have quite localized one dimensional character along the stepped line. Prof. Namba has conducted these ARPES works at BL-8, aiming for the fundamental understanding of the electronic structure of metal surfaces[1].

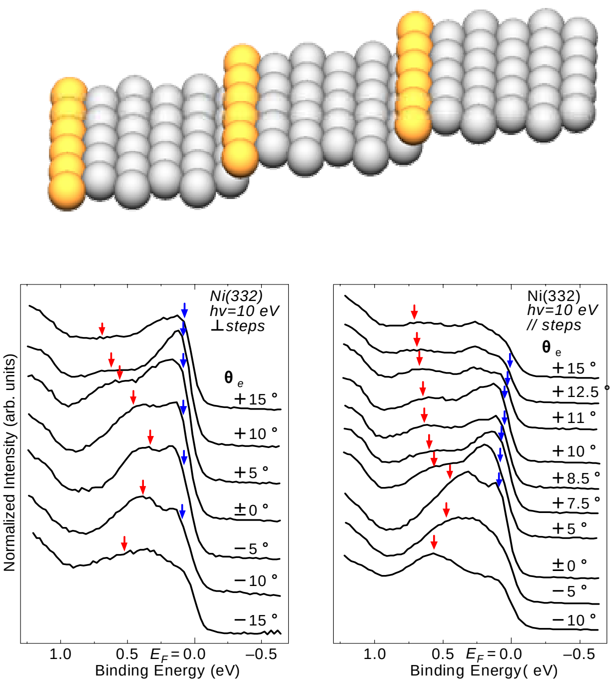

Fig. 1 Top: schematic model of Ni(332) stepped surface. Bottom left; ARPES spectra scanned perpendicular to the stepped line. Bottom right: those scanned along the stepped line.

(2) Surface structures of metal silicide

The growth mechanism of a metal silicide is rather complicated. Prof. Kido has investigated the initial growth mechanism of Ni silicide. Figure 2 shows Si 2p spectra as a function of Ni coverage2,3).

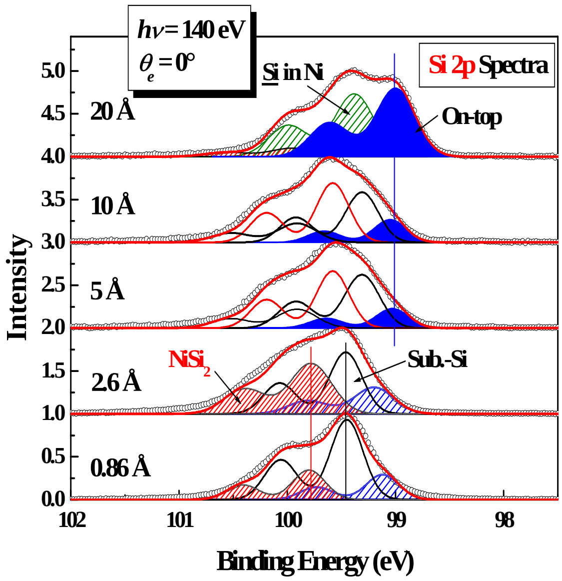

Fig. 2. Si $2p_{1/2,3/2}$ core level spectra observed at photon energy of 140 eV under normal emission condition for Ni coverage of 0.86, 2.6, 5, 10 and 20 Å. Observed spectrum was deconvoluted into components from Si on top (filled blue area), incorporated in Ni (slashed green area) and $NiSi_2$ (slashed re area). The blue, black and red bars indicate the energy positions (Si $2p_{3/2}$) for the surface-segregated Si, bulk Si and $NiSi_2$, respectively.

The spectral change indicates that Ni Si2 is formed at the initial stage and growth of surfactant Si atoms segregated out of the bulk substrate. However, it is risky to conclude the mechanism solely by Si 2p PES. Some additional and complementary method is necessary to establish the mechanism. Prof. Kido's group has established a system which combine medium energy ion scattering (MEIS) with PES to obtain more detailed surface information. They can measure both PES and MEIS without breaking vacuum.

Figure 3 is the MEIS spectra as a function of Ni coverage. Two peaks appear, in which the higher energy peak is due to scattering by Ni and the lower energy one by buried Si. The right figure is an enlarged scale to show Si spectra more clearly. We can decompose the spectra into four contributions. The spectral analysis confirms the PES results. This experiment demonstrates how effective the combined method of PES and MEIS is.

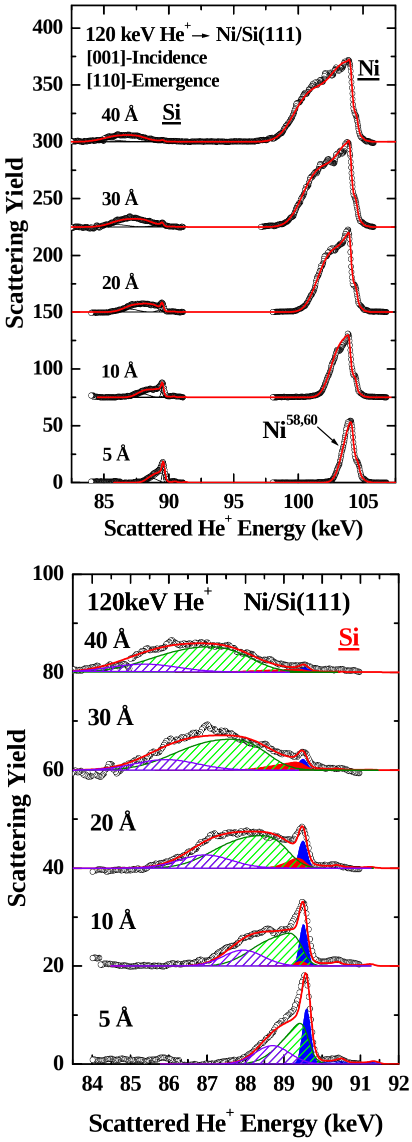

FIG. 3. (a) MEIS spectra observed for 120 keV He^+ ions incident along the [001] axis and backscattered to the [110] direction for Ni coverage of 5, 10, 20, 30 and 40 Å on Si(111). (b) Magnified MEIS spectra from Si. Red curves are the best-fitted spectra assuming appropriate elemental depth profiles. Filled blue and red areas are the components from Si on top and incorporated in Ni layer, respectively. Slashed green and purple areas deconvoluted come from Ni-silicide and Si substrate,

(3) XANES spectra from several Lithium compounds

It is known tough to measure Li 1s PES spectra with Al or Mg Kα radiation because of low cross section. Instead, Li K-XANES is very powerful probe for characterizing Li compounds. Figure 4 shows Li K-XANES of several Li compounds obtained with total electron yield method at BL-2[4]. It clearly shows that the spectral features are drastically changed dependent on the environment of Li atom. Recently, Li batteries attract much attention and Li K-XANES works as a very sensitive probe of characterizing the chemical change during the battery action.

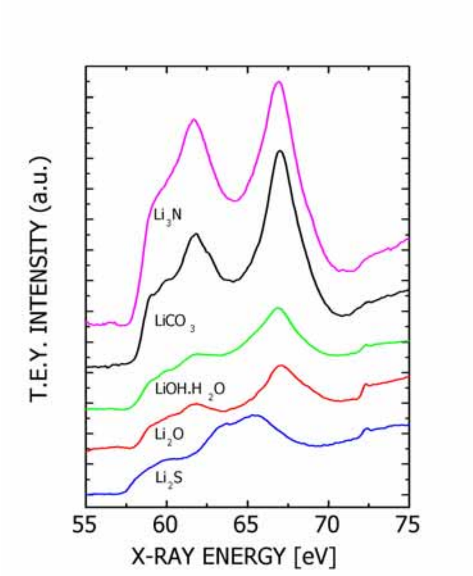

Fig. 4. Li K-XANES spectra from several Li compounds, taken with the electron yield mode.

(4) Orientation of liquid crystals studied by NEXAFS

Polarization dependent NEXAFS is a useful tool to investigate the orientation of molecules adsorbed on a substrate. Thermo-chemical reaction of PMDA-ODA produces polyimide films and mechanical rubbing process controls the orientation of polyimide local structure. To investigate how much the main chain is aligned, Oji et al studied azimuthal and polar angle depedent C-K and N-K NEXAFS and found that the polymer chain is anisotropically aligned along the direction of rubbing. They also studied the orientation of a molecule (4-pentyl-4-biphenyl carbonitrile:5 CB) evaporated on the PMDA-ODA film. This is a typical liquid crystal. At low coverage, 5CB lies down slightly tilted along the polyimide oriented direction. The molecule gradually stands up at higher coverage. This information obtained by polarization dependent NEXAFS is very useful for future design of liquid crystal. This work has been done in collaboration with JSR(Japan Synthetic Rubber) Co[5].

(5) Micro-machining with the LIGA process

The center puts special weight on micromachining with the LIGA process and in fact, 4 beamlines are dedicated for this subject. Recently, Prof. Sugiyama invented a new technique, so-called 'Plane pattern to Cross section Transfer (PCT)' method, which is schematically drawn in Fig. 5.[6)]

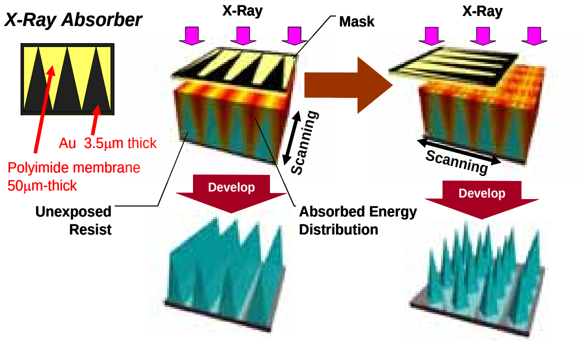

Fig. 5 PMMA resist beneath an X-ray mask is scanned during the SR irradiation. When the mask has a wedge-shape, the scanned resist is etched as a grating. If this resist is further scanned perpendicular to the previous direction, it is etched as needles. This idea makes complicates structure s with a simple mask

FUTURE PLANS

In Japan, there are many synchrotron facilities actively working and/or constructing. For more output of new applications, we have to develop unique beamlines that do not exist in other facilities. For this reason, we plan to develop an infrared beamline whose performance is not dependent on the ring energy or ring size, but on the beam current times acceptance angle of the beam. Although the acceptance angle of the SR beam port is limited to 30 h mrad x 30 v mrad, insertion of mirrors to focus the light source point makes us possible to increase the acceptance angle substantially, as schematically shown in Fig. 6. This is the idea similar to Prof. Yamada for mirrorcle. Since the reflectance in the infrared region is almost 100 %, multiple mirror system will provide us a very intense infrared beamline. We plan to perform the infrared microscopy experiment with the spatial resolution of 5 mm at 2000 cm-1 (diffraction limit). In order to overcome the limit, we further plan to install the near field optics and aim the spatial resolution of submicron.

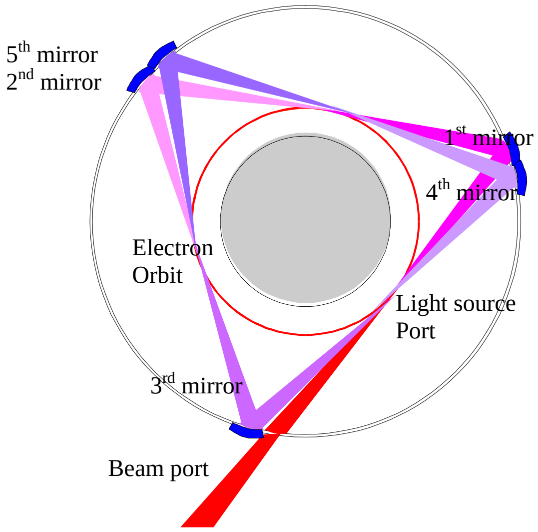

Fig. 6. Schematic drawing of the multimirror system. By installing the 1sr mirror, the beam intensity becomes double and further installation of mirrors at appropriate positions increase by the number of mirrors.

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