Materials Science

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Critical phenomena of lattice and charge systems in β-$Na_{1/3}V_2O_5$

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Introduction

A series of beta-vanadium bronzes (β-$A_{1/3}V_2O_5$) exhibits some exotic physical properties under high pressure (HP).

A basic structure is common to all β-$A_{1/3}V_2O_5$ series, $P2_1/a$ space group. In spite of the common structure, physical properties are quite different and depend on a carrier number. When the A site is occupied by an ion having 1+ valence (Na^{1+}...), the system shows superconductivity under HP [1]. On the other hand, when the A site is occupied by an ion having 2+ valences (Sr^{2+}...), the system shows devil's flower-like behaviours under HP [2]. However, most of the samples (A = Na, Sr and so on) commonly show a charge ordering with $b'=\underline{\mathbf{6}}b$ unit cell at low temperature in spite of a different modulation of the charge instability above metal-insulator (M-I) transition at *T*c [2].

To study an intrinsic difference among $A_{1/3}V_2O_5$ system, we have particularly focused upon critical phenomena of lattice and charge systems. A critical property of a sample well reflect a universal class where the sample belonging to. In this time, we will report results of a measurement of the critical phenomena of $Na_{1/3}V_2O_5$.

Experimental

Experiment was carried out at BL-4C of Photon Factory. For separating information of lattice (atomic shift) and charge, we used a resonant x-ray scattering (RXS) technique. An RXS intensity at the main edge of V-K absorption edge (around 5.47 keV) well reflects the charge disproportionation at V sites.

Results

Figure 1 shows energy spectra of 0 10/6 0 reflection measured at 100 K and 128.4 K. A fluorescence spectrum is also shown by a solid line. On-resonant intensities around E = 5.485 keV rapidly decreases rather than off-resonant intensities around E = 5.44 keV as the temperature increases near the critical temperature, Tc = 128.96 K. It means that the atomic shift is a primary order parameter, while the charge order is a secondary order parameter. Because the on-resonant intensity well corresponds to the charge ordering, while the off-resonant intensity corresponds to the atomic shifts.

Figure 2 shows a temperature dependence of the intensity measured at E = 5.482 keV (on resonant) and E = 5.44 keV (off resonant). Dotted curves represent the fitting results using $f(T) = ((Tc-T)/Tc)^{2\beta(\beta')}$. The critical region was set as $126.5<T<128.5$ for eliminating a effect of a diffuse scattering. Finally, we obtained the critical exponent β = 0.282(47) for the off-resonant data and β' = 0.559(41) for the on-resonant data. The relationship between β and β' is β'~ 2β, where it obeys a naive Landau prediction for the secondary order parameter.

It is suggested that the M-I transition at Tc of $A_{1/3}V_2O_5$ system is driven by a ***b*=1/6*** lattice instability. The charge modulation tends to adjust the lattice modulation.

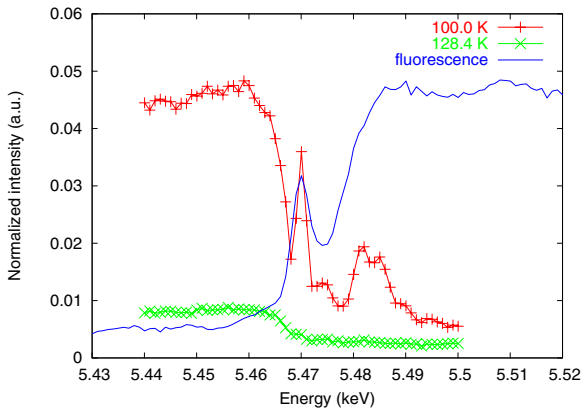

Fig. 1. The RXS and the fluorescence spectrum of β-$Na_{1/3}V_2O_5$.

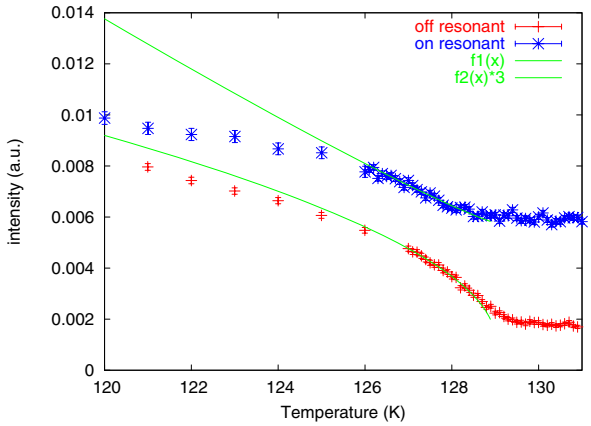

Fig. 2. Temperature dependence of the intensity measured at the on-resonant (E = 5.482 keV) and the off-resonant (E = 5.44 keV) energies.

References

[1] T. Yamauchi *et al.*, Phys Rev. Lett. **89**, 057002 (2002).
[2] T. Yamauchi *et al.*, private communications.