# Impurity doping effects on orbital order in MnV2O4

K. Hemmi[1], R. Fukuta[1], S. Miyasaka[1], S. Tajima[1],
A. Nakao[2], H. Nakao[2], R. Kumai[2], Y. Murakami[2]
[1]Department of Physics, Osaka University, Osaka 560-0043, Japan
[2]KEK PF/CMRC, Tsukuba 305-0801, Japan

Spinel-type vanadium oxides $AV_2O_4$ are ideal materials to investigate spin, orbital and charge ordering in a geometrically-frustrated system because the $V^{3+}$ ($3d^2$) ions have orbital degrees of freedom of $t_{2g}$ electrons. We investigated impurity doping effects of $Cr^{3+}$ ($3d^3$) and $Mo^{3+}$ ($4d^3$), which have no orbital degrees of freedom, for the $V^{3+}$ site of $MnV_2O_4$. We found the suppression of the orbital ordering and the difference of electronic structures depends on impurities.

$Mn(V_{1-x}M_x)_2O_4$ ($M$=Cr, Mo) single crystals were grown by floating-zone method. Magnetization measurements were carried out with a SQUID magnetometer. The powder X-ray diffraction experiment was carried out at BL-8A of the Photon Factory, KEK. Resistivity was measured by a standard four-probe method. Optical reflectivity measurements were performed with FTIR spectrometer.

Fig. 1 shows the phase diagrams of $Mn(V_{1-x}M_x)_2O_4$ ($M$=Cr, Mo) determined by the magnetic susceptibility. In $MnV_2O_4$, there are the collinear ferromagnetic phase transition at $T_N$=59K and the orbital ordering transition accompanied by structural transition at $T_{OO}$=54K. These are consistent with the previous reports [1, 2]. $T_{OO}$ is suppressed with increasing impurities and disappears above $x$=0.12 and 0.08 in Cr-doped and Mo-doped samples, respectively. It was confirmed that the structural transition temperatures of the doped samples almost coincide with the $T_{OO}$. In addition, we found that while Cr-doped samples remain Mott insulators, Mo-doped samples become metallic with increasing Mo content by resistivity and optical measurements.

These results indicate that electrons remain localized in the Cr-doped system, while they become itinerant in the Mo-doped one.

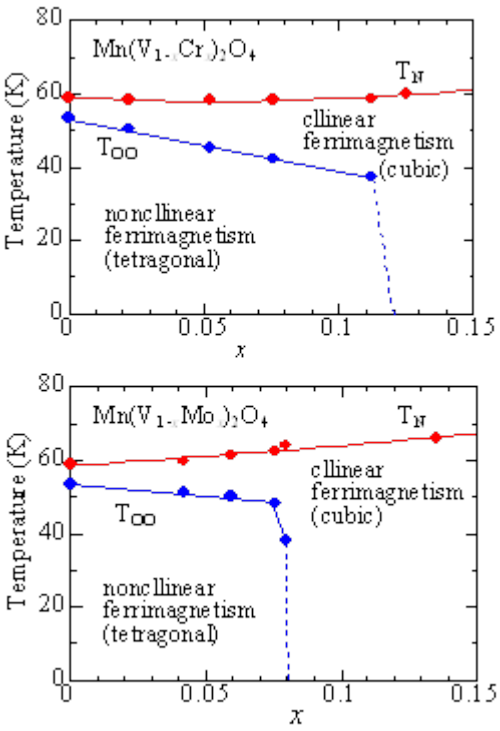


Fig. 1. Phase diagrams of $Mn(V_{1-x}M_x)_2O_4$ (M=Cr, Mo).

[1] R. Plumier and M. Sougi, Solid State Commun. **64**, 53 (1987).
[2] S. Suzuki *et al.*, Phys. Rev. Lett. **98**, 127203 (2007).