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Magnetic and Electronic Properties of Reduced Rutile

Ti$_{1-x}$Mn$_x$O$_{2.8}$ Thin Films

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Magnetic and electronic properties of Mn-doped rutile TiO$_{2.8}$ thin films grown on Al$_2$O$_3$(0001) substrates by a sol-gel method have been investigated. Rutile Ti$_{1-x}$Mn$_x$O$_{2.8}$ thin films with $x = 3.9$ at.% were found to exhibit ferromagnetism at room temperature by vibrating sample magnetometry (VSM) with a saturation magnetic moment ($M_S$) of about 0.75 $\mu_B$ per Mn ion as shown in Fig. 1. The films with $x = 5.6$ at.% also showed room-temperature ferromagnetism but with reduced $M_S$ compared to $x = 3.9$ at.%. However, the films with $x = 2.5$ at.% showed no ferromagnetic behavior. Hall measurements revealed that all the Mn-doped films are p-type semiconductors with the hole concentration of about $10^{19}$ cm$^{-3}$ while the undoped films n-type with electron concentration of about $10^{18}$ cm$^{-3}$. The electrical conductivity of the Mn-doped films were found to decrease with increasing Mn content. Thus, the ferromagnetism in the present rutile Ti$_{1-x}$Mn$_x$O$_{2.8}$ films is not attributable to the hole carriers but to a direct ferromagnetic coupling between neighboring Mn ions via an electron trapped in nearby oxygen vacancy.

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![Figure 1. VSM measurement result of rutile TiO$_{2.8}$:Mn films at room temperature.](image-url)