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Electrically-induced ferromagnetism at room temperature in (Ti,Co)O_2: carrier-mediated ferromagnetism[1]

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Oxide-diluted magnetic semiconductors (DMS) is expected to have high Curie temperature via carrier-mediated ferromagnetism through heavy electron mass and large electron carrier density. We have studied various oxide-DMS such as (Zn,Mn)O [1], and discovered room temperature ferromagnetism in (Ti,Co)O_2 [2]. The origin of ferromagnetism has been discussed for a decade. Previously, the control of ferromagnetism was demonstrated through carrier control by chemical doping [3]. But it was difficult to exclude the defect-mediated ferromagnetism, since the electron donor was the oxygen vacancy [4]. In order to evidence the carrier-mediated ferromagnetism, the electric field control of ferromagnetism is useful [5]. The control of ferromagnetism at room temperature is also important for implementation of spintronic devices. By gating with electric double layer transistor, the ferromagnetism was induced at room temperature, representing electron carrier-mediated ferromagnetism [6]. Chemical doping study in (Ti,Co)O_2 for wider range of carrier density exhibited clearer paramagnetic insulator to ferromagnetic metal transition with increasing carrier density [7]. At a medium carrier density, a ferromagnetic insulator phase appeared possibly related with a phase separation between ferromagnetic and paramagnetic phases. Also, a superparamagnetic phase appeared for excessively reduced sample. Taking all these results into account, previously proposed extrinsic mechanisms such as oxygen vacancy-mediated mechanism [4], metal segregation [8], and superparamagnetism [9] are not correct picture of the ferromagnetism. This study was in collaboration with Y. Yamada, K. Ueno, M. Kawasaki, H. T. Yuan, H. Shimotani, Y. Iwasa, L. Gu, S. Tsukimoto, Y. Ikuhara, A. Fujimori, and T. Mizokawa.

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