DILUTE MAGNETISM AND MOSSBAUER STUDY OF NANO SnO_2 BASED OXIDES DOPED WITH ^{57}Fe, PREPARED BY SOL-GEL METHOD

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The SnO_2 doped with Fe ions, which shows a ferromagnetic behaviour at room temperature is expected to be used as semiconductor for spintronics [1, 2]. It is recently found that the addition of both dilute magnetic ions such as (Fe, Co) ions enhances the behaviour of magnetization [3]. We have prepared powders with 20-40 nm in diameter using a sol-gel method. First of all the solution are prepared by addition of ethylene glycol and citric acid solution to mixed chloride solutions of TM and Sn^{2+}, and condensed by heating to 80^{o}C. The gel obtained was fired at about 250^{o}C, and annealed at 550^{o}C. Especially (1%Fe, 0.5%-2%Co) co-doped SnO_2 shows the relatively large magnetization, compared with SnO_2 doped with only Fe or Co ions. XRD showed no peaks of the impurities, but only peaks of the rutile structure of SnO_2. ^{57}Fe Mössbauer spectra consist of two paramagnetic doublets and one broad sextet of high-spin Fe^{3+} species. The magnetic sextet with broad peaks is drastically modulated by doping with 0.5%–2% Co and 1% Fe. With the increase of Co ions, magnetic components in Mossbauer spectra of 1% Fe doped SnO_2 decreased and the saturation magnetization also decreased. With the increase of Fe ions for 1%Co doped SnO_2, the magnetization increased and a sharp sextet of α-Fe_2O_3 appeared additionally at more than 4 % Fe doping. The sextet may not be pure α-Fe_2O_3, but Sn substituted Fe_2O_3, which shows the weak ferromagnetism at room temperature. After annealed further in vacuum (10^{-4} torr), some doped SnO_2 enhanced the magnetic hysteresis. The magnetic defects produced by annealing are one of important factors for induced ferromagnetism.

On one hand, SnO_2 doped with 1%$Fe^{3+}$and 1% V^{5+}(0.46nm in diameter) showed the very weak magnetic hysterics, and the Mossbauer spectrum did not show any broad magnetic sextet but only sharp sextet of hematite in addition to two doublets of paramagnetic $Fe^{3+}$and relaxation peaks. That is why V^{5+} (0.46nm in diameter) cannot be incorporated into SnO_2 and very active in fire treatment, and may induce the precipitation of Fe_2O_3. On the other hand, the addition of Sb^{5+} is effective to the incorporation into SnO_2 matrix because Sb^{5+} in ionic radius (0.60nm) is between Fe^{3+}(0.55nm) and Sn^{4+}(0.69nm), to the increase of carrier density of the SnO_2 matrix and to the enhanced magnetization of (Fe, Co) doped SnO_2. 3% Sb ion doping showed the maximum of saturation magnetization for 2%Fe+1%Co doped SnO_2. Mossbauer spectra can be decomposed into two doublets of paramagnetic Fe^{3+} and two sextets for (various % Fe, 1%Co, and 3%Sb) doped SnO_2. The relationship between the area intensity of broad magnetic component and the saturation magnetization is obtained. Another sextet may be like hematite. These results are shown herewith Mossbauer spectra.

[1] JMD Coey et al. Nature Materials 4, 173 (2005). [2] K. Nomura et al, Phys. Rev. B 75, 184411 (2007). [3] K. Nomura et al, J. Appl. Phy. 110, 083901 (2011).

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