Co-doped Gd_2O_3nanorods: Structure and magnetism

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1. Introduction

Diluted magnetic semiconductors (DMSs) have attracted a considerable amount of attention owing to their promising applications in spintronics and magneto-optics [1,2]. Over the past decades, the enhancement of DMS magnetic properties such as Curie temperature has been the focus of intense research. Curiously, in this context, TM-ion-doped rare-earth (R^{3+}) oxides have yet to be given significant consideration. Binary rare-earth oxides are the most stable rare-earth compounds, in which rare-earth ions typically hold the trivalent state. In TM ions, magnetic moment arises from the partially filled outermost 3d electrons, whereas in R^{3+} ions, magnetic moment arises from the inner 4f incomplete sub-shell. Considering the importance of R^{3+} rare-earth oxides, particularly the broad interest in Gd-based oxides, Gd_2O_3 may be an advanced potential DMS candidate after doping with Co^{2+} ions. The ferromagnetism of the Gd atom below 289 K drives the study of Gd_2O_3's magnetic properties.

2. Experimental method and Results

We synthesized $Gd_{2-x}Co_xO_3$ (x = 0, 0.02, 0.04, 0.06) nanorods via the following hydrothermal procedure. First, Gd_2O_3 powders and stoichiometric amounts of $Co(NO_3)_2 \cdot 6H_2O$ were dissolved in diluted nitric acid solution. Then, 25% NH_4OH solution was slowly added to the above solution under vigorous stirring, adjusting the pH value of the new colloidal solution between 10 and 12. The hydrothermal reaction was conducted at 190°C for 20 h in a Teflon-lined autoclave. The solid products were collected by filtration and washed with distilled water. Subsequent 3 h heat treatment at 550°C inducedthe formation of Co-doped Gd_2O_3 nanorods. From FESEM and TEM images, the morphology is rod-shaped with less than 100 nm diameter and 200 nm–2 μm long. With increasing Co-doping concentration, the length and diameter of the nanorods decreases. EDS elemental mappings shows the uniform distribution of the Gd, Co, and O elements in the crystal.

3. Discussion and Conclusions

XRD, Raman, XPS, and TEM measurements showed the samples to have a single cubic phase structure of Gd_2O_3 doped with Co^{2+} cations, without any cobalt clusters. The XPS spectra revealed the Co ions to be in divalent Co^{2+} states and in octahedral symmetry. All the samples exhibited mostly paramagnetism along with very weak antiferromagnetism; this was due to the non-interacting nature of the Gd^{3+} ions which, incapable of undergoingstrong ferromagnetic interaction with the neighboring ions. The samples also exhibited negative Curie–Weiss temperature due to the super-exchange interaction of Gd^{3+} and Co^{2+} ions via O^{2-} ions and coupling between Co^{2+}–Co^{2+} pairs, indicating the presence of very weak antiferromagnetism in the $Gd_{2-x}Co_xO_3$ (x = 0, 0.02, 0.04, 0.06) nanorods.

4. References

[1] H. Ohno, Science **281**, 951 (1998).

[2] S. A. Wolf *et al*., Science **294,** 1488 (2001).