Structural analysis and room temperature ferromagnetism of $Y_2O_3:Co^{2+}$ nanorods, synthesized by controlled hydrothermal method

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1. Introduction

In present day research, diluted magnetic oxide (DMO) system are one of the promising candidates for potential spintronics application, because they display room temperature ferromagnetism1. The development of today's spintronics research has provided many possibilities of revolutionizing semiconductor technology2. There are so many previous researches till date focusing on ZnO, TiO_2, SnO_2 systems of a low band gap around 3.0 eV, but here we have focused our research on DMO of nearly insulating system with a medium band gap ~ 5.0 eV doped with transition metal ions. For the hybrid device application in the present day research, high κ dielectric systems like HfO_2 and Y_2O_3 are of great interest. Recently, few researchers have reported the existence of room temperature ferromagnetism in transition metal ion doped HfO_2 and Y_2O_3 thin films and nanocrystals[3], but little attention has been given to one dimension (1D) nanostructures of it. Studies on 1D semiconductor nanostructures has given huge interest form the last one decade, because they have extraordinary lengths, flexibility, shape anisotropy and unique electronic features due to their 1D quantum confinement effect. Here, we have synthesized $Y_{2-x}Co_xO_3$; (x = 0.00, 0.04, 0.08) nanorods by a cheap and easy hydrothermal method and studied the room temperature magnetic property for pure and transition metal ion Co^{2+} doped Y_2O_3 nanorods for the first time. The hydrothermal method is used for the preparation of 1D nanostructure because; it requires neither templates nor catalysts to yield the product continuously. The details of synthesis mechanism, structural and microstructural analysis along with the explanation of the existence of room temperature ferromagnetism (RTFM) in our studied materials have been discussed here. The combination of ferromagnetism with high κ dielectric characteristics of Y_2O_3 doped with Co^{2+} ions will enhance the integration of complementary metal-oxide semiconductor with spintronic technology.

2. Experiment method, results and discussion

For the synthesis of $Y_{2-x}Co_xO_3$; (x = 0.00, 0.04, 0.08)nanorods using hydrothermal method, 10% NH_4OH solution was added to the appropriate amount of stock solution of the metal ions to get the hydroxide precipitate of it. The white slurry was placed in a stainless steel Teflon-lined autoclave for hydrothermal treatment at 190°C for 20 h. The autoclaved product was then washed several times with water and calcined at 550°C for 4hto get the final product. X-ray diffraction, Raman spectra and X-ray photoelectron spectroscopy were carried out which indicated the formation of pure cubic phase structure of Y_2O_3 doped with Co^{2+} ions without any secondary phase formation. The growth mechanism of the synthesized nanorods has been proposed and it grew along [100]

directions.[4] The scanning electron microscopy (SEM) and transmission electron microscopy (TEM) images support the growth mechanism of the nanorods with average diameters of 100 nm and length of 2 μm. Magnetic property of all the samples are studied by vibrating sample magnetometer (VSM) analysis. The M-H curve of pure Y_2O_3 nanorods shows almost linear diamagnetic curve whereas Co^{2+} doped Y_2O_3 exhibits clear signature of ferromagnetism. The existence of room ferromagnetic behavior in Co^{2+} doped Y_2O_3 is mainly due to the existence of oxygen vacancies originated after the doping of transition metal ion in the host lattice. Oxygen vacancies are acting as defect centers in the bound magnetic polaron modelto account for this dilute magnetic oxide of medium band gap with low carrier concentration.[5] The existence of intrinsic defects such as oxygen vacancies in our studied materials $Y_{2-x}Co_xO_3$ nanorods has been further supported by the analysis of room temperature photoluminescence spectra.

3. Conclusion

In conclusion, we have synthesized pure and Co doped Y_2O_3 nanorods using a simple and inexpensive hydrothermal process. Pure Y_2O_3 nanorods exhibit linear diamagnetism whereas Co doped Y_2O_3 nanorods show room temperature ferromagnetism. The existence of ferromagnetism is due to the incorporation of transition metal ion in Y_2O_3 nanorods which is again due to the creation of oxygen vacancy during defect formation in the host lattice. The ferromagnetic behavior is mainly due to the defect mediated mechanism in the framework of bound magnetic polarons. The presence of defect related oxygen vacancy is confirmed by photoluminescence measurements. The observation of room temperature ferromagnetic behavior in our studied materials suggests a generic feature of Co doped high κ oxides as a good candidate for DMO. Such modulation in the magnetic behavior of DMO via oxygen vacancy by means of doping transition metal ion can be exploited for potential applications in spintronics.

4. References

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