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Enhancement of Ferromagnetic Properties in Epitaxial (001) BiFeO₃ Films by Co Doping

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The magnetoelectric (ME) effect, which is the induction of magnetization by an electric field or polarization by a magnetic field has enabled multiferroics to become materials with exciting possibilities. Among them, BiFeO₃ (BFO) has been intensively studied, because of having a large polarization at room temperature. In spite of its superiority in electrical properties, the presence of antiferromagnetism (or weak ferromagnetism) has inhibited the observation of ME effect in BFO films. In this paper, we report the enhancement of ferromagnetic properties in epitaxial (001) BFO films achieved by Co doping. Epitaxial (001) BFO films with 800-nm thickness have been successfully grown on (001) SrTiO₃ (STO) substrate by on-axis sputtering technique. The Co doping ratio is controlled by adjusting Co chips on the BFO target during deposition. At room temperature, the pure BFO film shows antiferromagnetic behavior, as shown in Fig. 1(a). As the Co-doping ratio increases, both the saturation magnetization and the coercivity dramatically increase up to 69 emu/cc and 680 Oe, respectively, as shown in Fig. 1(b). We believe that the Co plays a role of ferromagnetic particles in antiferromagnetic BFO film. Such ferromagnetic particles can easily increase the saturation magnetization and ferromagnetic particles in antiferromagnetic BFO film can induce the exchange bias, which is considered to be the reason of the increase in the coercivity.

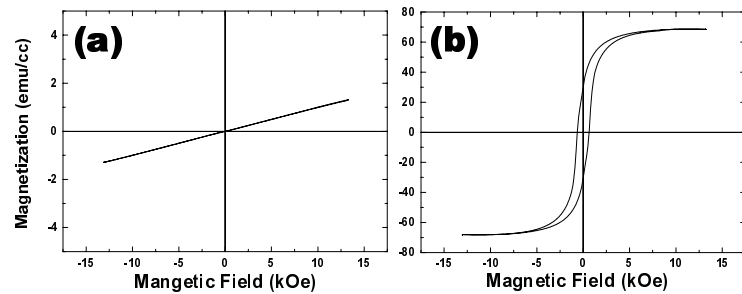


Fig. 1. M-H hysteresis loops of the pure BFO film (a) and the Co-doped BFO film (b).

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Synthesis, Structural Details and Induction of Superconductivity in Ga_{1-x}Pb_xSr₂Y_{1-y}Ca_yCu₂O₇ (x=0.0 to 0.6 & y=0.0 to 0.5)

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We have synthesized Ga_{1-x}Pb_xSr₂Y_{1-y}Ca_yCu₂O₇ (x = 0.0 & y = 0.0 to 0.5; y = 0.0 & x = 0.0 to 0.6; x = 0.30 & y = 0.2, 0.3 & 0.35) 1212 type compound. The samples are synthesized by solid state reaction route in air with calcination at 980C, and 1000C & sintering at 1020C with intermediate grindings. All the compounds have single phase orthorhombic structure with space group Ima2, Fig.1. shows the Reitveld refinement for all the compositions. For GaSr₂Y_{1-y}Ca_yCu₂O₇ composition it shows that there is decrease in lattice parameter a, b and c with increasing Ca and it is soluble up to y<0.50, Table 1. The room temperature conductivity also improves with increasing Ca content. For Ga_{1-x}Pb_xSr₂YCu₂O₇ composition there is increase in a, b and c with increasing Pb content and it is soluble up to x<0.70. The R-T measurement shows as GaSr₂Y_{1-y}Ca_yCu₂O₇ and Ga_{1-x}Pb_xSr₂YCu₂O₇ compositions are highly semiconducting though compositions (Ga_{0.7}Pb_{0.3})Sr₂Y_{1-y}Ca_yCu₂O₇ (y = 0.2, 0.30 & 0.35) have less semi conductivity.

Sample	a(Å)	b(Å)	c(Å)
GaSr ₂ YCu ₂ O ₇	22.7953 (12)	5.4807 (2)	5.3929 (2)
GaSr ₂ Y _{0.7} Ca _{0.3} Cu ₂ O ₇	22.7831 (14)	5.4741 (2)	5.3870 (3)
Ga _{0.5} Pb _{0.5} Sr ₂ YCu ₂ O ₇	23.1970 (15)	5.3992 (2)	5.4360 (3)
Ga _{0.4} Pb _{0.6} Sr ₂ YCu ₂ O ₇	23.3103 (19)	5.4087 (4)	5.4260 (4)
Ga _{0.7} Pb _{0.3} Sr ₂ Y _{0.65} Ca _{0.35} Cu ₂ O ₇	22.8624 (33)	5.4531 (7)	5.3830(7)

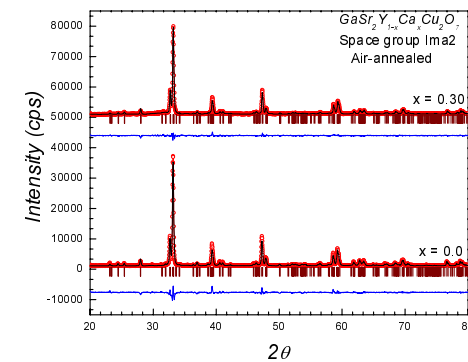


Fig. 1. Fitted and observed X-ray diffractions for GaSr₂Y_{1-y}Ca_yCu₂O₇ with y = 0.0 and 0.30 samples.