Preparation of Ferromagnetic Semiconducting ZnO-(Fe,Zn)$_3$O$_4$ Heterogranular through Chemical Solution Reactions

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Introduction

Heterogranular films composed of an insulating matrix material and dispersed ferromagnetic nano-paraticles have attracted increasing attentions in electrical and electronics industries, because of characteristic magnetic and electromagnetic properties such as magnetoresistance. Co-Ta-O[1] and Fe-Si-O heterogranular films have been prepared with gas-phase deposition techniques. Also, our group demonstrated preparations of Fe-Tb-O and Co-Ce-O heterogranular films by electrochemical reactions.[2,3] In most of granular films already prepared, insulating oxide materials such as CeO_2 and Al_2O_3 are used as the matrix. Here, we show a semiconducting ZnO-ferromagnetic $(Fe,Zn)_3O_4$ heterogranular film and the preparation process with chemical reactions.

Preparation of ZnO-(Zn,Fe)$_3$O$_4$ heterogranular film

ZnO-$(Zn,Fe)_3O_4$ heterogranular film was prepared by following three steps. First step is chemical deposition of ZnO film[4,5] by immersing a glass substrate (Corning#1737) only by immersing substrates into aqueous solution containing zinc nitrate hydrate and DMAB at 333K. Second step is chemical introduction of Fe impurity into the ZnO film, which result in the formation of ferromagnetic transparent $Fe_{0.34}Zn_{0.66}O$ film with wurtzite structure.[6] And, then third step is heating the $Fe_{0.34}Zn_{0.66}O$ film at 573-773K in vacuum.

Characterization of ZnO-(Zn,Fe)$_3$O$_4$ hetero- granular film

$Fe_{0.34}Zn_{0.66}O$ film had a wurtzite structure characteristic to ZnO. Heating at temperature of 773K gave a thermal transformation of the $Fe_{0.34}Zn_{0.66}O$ film into a mixture of ZnO with characteristic wurtzite structure and $(Zn,Fe)_3O_4$ particles with spinell cubic structure characteristic to ferromagnetic magnetite in the formula of Fe_3O_4.

Figure shows magnetization curves for the $Fe_{0.34}Zn_{0.66}O$ and $(Zn,Fe)_3O_4$ films at room temperature. At room temperature, $Fe_{0.34}Zn_{0.66}O$ film showed ferromagnetic feature. ZnO-$(Zn,Fe)_3O_4$ film prepared by heating at 773K showed increased Ms and increased Hc. And, the ZnO-$(Zn,Fe)_3O_4$ film was a n-type semiconductor of 11Ωcm with $1x10^{14}cm^{-3}$ in carrier concentration and $83cm^2V^{-1}s^{-1}$ in mobility. And, the ZnO-$(Zn,Fe)_3O_4$ film showed a magnetoresitant effect at room temperature. Although the $Fe_{0.34}Zn_{0.66}O$ film showed high optical transparency in visible light region, the ZnO-$(Zn,Fe)_3O_4$ film showed black appearance because of the existence of $(Zn,Fe)_3O_4$ in the film.

Reference

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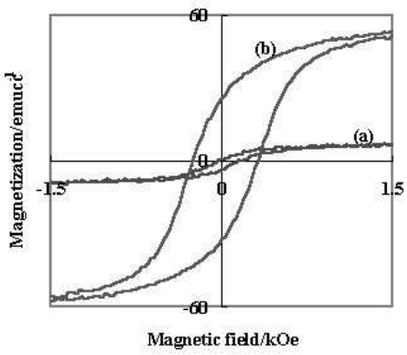

Figure Magnetization curves for Fe0.34Zn0.66O(a) and ZnO-(Zn,Fe)3O4(b) films at RT.