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TEM of Nanostructure of Cu and Ti doped Sm-Co magnetic materials

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Sm_2Co_{17} and $SmCo_5$ are the two compounds having attractive magnetic properties such as high anisotropy and Curie temperature [1]. In this paper we report the nanostructures of both bulk and films of Cu and Ti doped Sm-Co magnetic materials. The bulk samples of composition $Sm(Co_{7.05-x}Cu_xTi_{0.25-0.3})$ x=0.4~0.8 were prepared by arc melting and then annealed at 1165 ºC for 3 hours, followed by annealing at 825 ºC for 8 hours and then slowly cooling down to 550 ºC with rate of 1 ºC/min. Multilayer thin films were sputtered on Si substrate with a Cr underlayer of 90 nm and cover layer of 18 nm. The structure of the thin films is [($SmCo_5$)45Å/(CuTi)XÅ]xY, (X = 2-10, Y =28 - 34). The films were annealed at 525 ºC for 30 minutes. The coercivities of bulk samples with high concentration of Cu x > 0.65 are higher than 8 kOe at room temperature but drop quickly with increasing temperature. The coercivities of bulk samples with low concentration of Cu x<0.6 are below 4 kOe at room temperature but increase with increasing temperature. Hysteresis loops show that the film [($SmCo_5$) 45Å/(CuTi)5Å] x40 has giant coercivity of 50.4 kOe at room temperature. In comparison, $SmCo_5$ single layer and [($SmCo_5$) 45Å/Cu5Å] x40 multilayers show coercivities less than1 kOe.

Figure 1 shows the bright field TEM image and HRTEM image of a bulk sample. The grain boundary phase is clearly revealed by HRTEM image. The width of this phase is about 8 nm. EDX analysis shows the majority phase has higher concentration of Co while the grain boundary phase has higher Cu concentration. The volume fraction of the grain boundary phase increases with Cu concentration. The grain boundary phase has the Cu_5Ca type structure and has high anisotropy. Therefore, the coercivity at room temperature increases with Cu concentration. At high temperature both the anisotropy and the Curie temperature of the $Sm(Co,Cu)_5$ phase decreases with increasing Cu content.

Figure 2 and Figure 3 are HRTEM images of films No.1 [($SmCo_5$)45Å/(CuTi)5Å]x40 and film No. 3 [($SmCo_5$)45Å/Ti5Å]x40. Film No.1 has a structure of a precipitate phase with a grain size of about 5 -10 nm distributed in a matrix. Film No. 2 has a single phase with grain size of about 15 nm. Both X-ray diffraction and electron diffraction indicate the formation of $SmCo_5$ phase which has high anisotropy responsible for the high coercivities. In film No.1 the appearance of the second phase is due to the extra Cu which promotes the formation of the second phase. Cu in the second phase acts to decrease the exchange coupling behavior to give the giant coercivity. Because of the high anisotropy of Co_5Sm this system offers the smaller magnetic grains stable for high density recording media.

[1] C.H.Chen, M.S. Walmer, M.H. Walmer, S. Liu, and E. Kuhl, J. Appl. Phys. 83, (1998) 6706.
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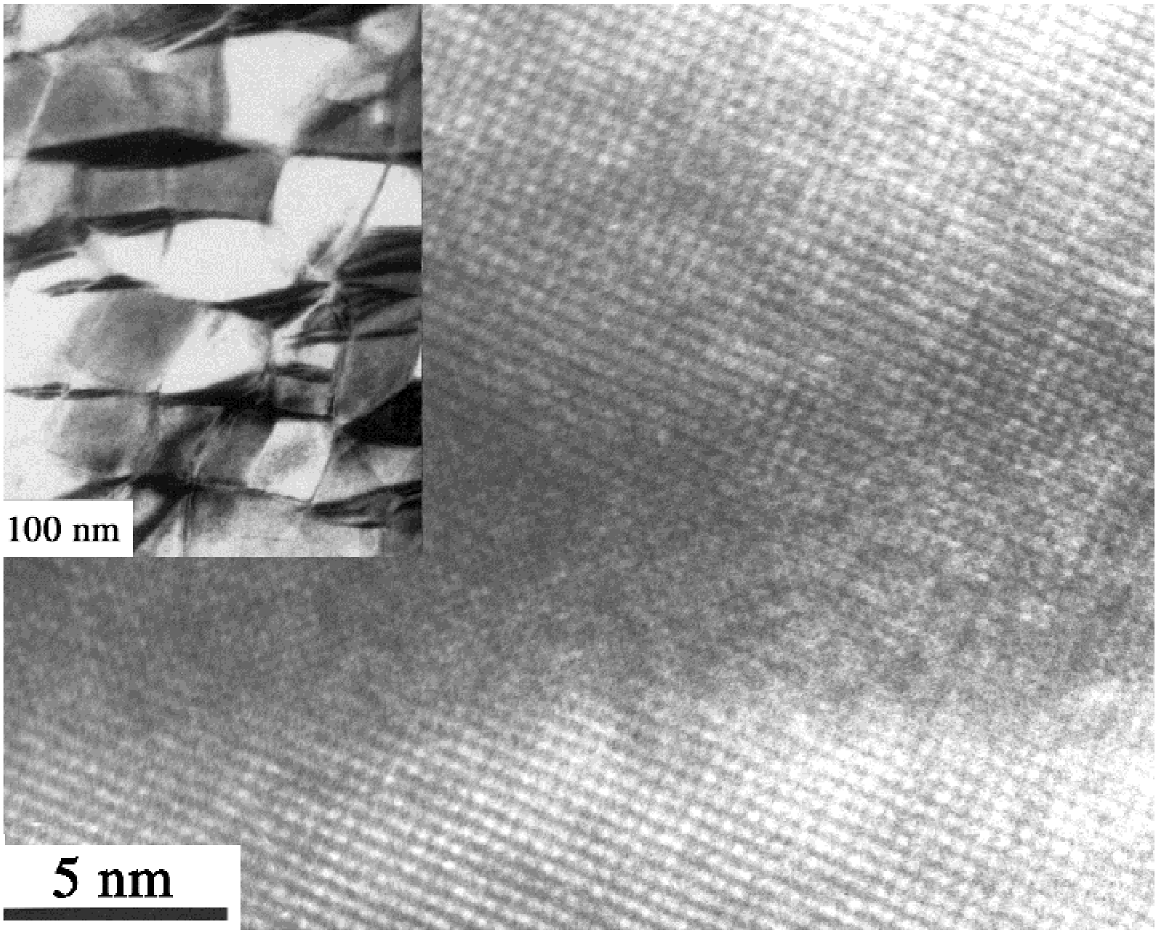

FIG. 1. Bright field and HRTEM image of $SmCo_{6.1}Cu_{0.6}Ti_{0.3}$.

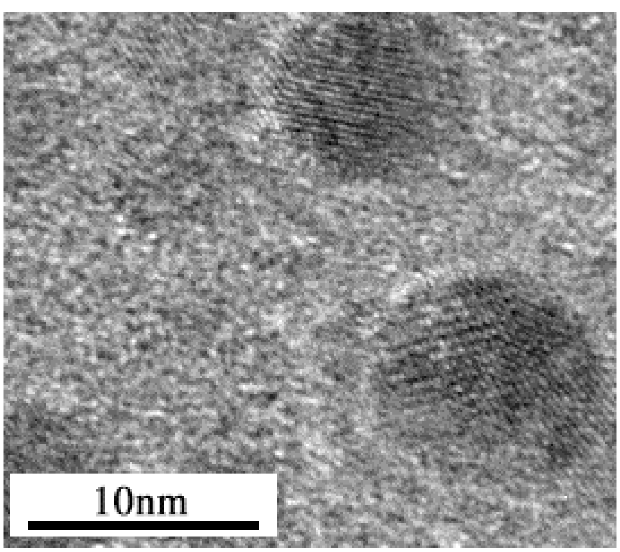

FIG. 2. HRTEM image of film No. 1 [$(SmCo_5)$45Å/(CuTi)5Å]x40.

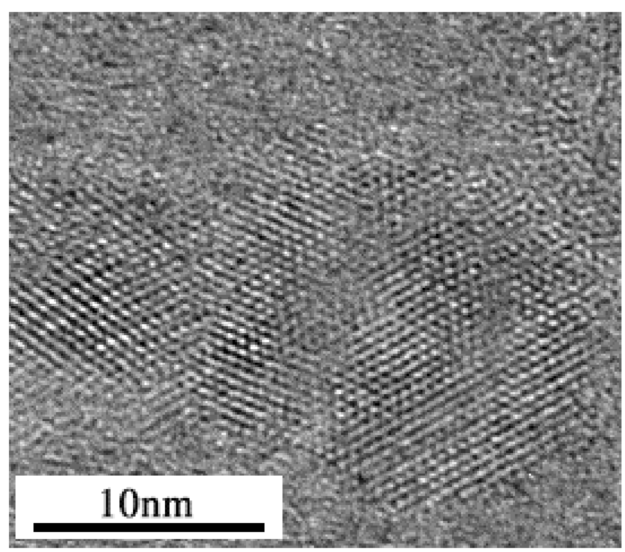

FIG. 3. HRTEM image of film No. 3 [$(SmCo_5)$45Å/Ti5Å]x40.

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