*33rd EPS Conference on Plasma Phys. Rome, 19 - 23 June 2006 ECA Vol.**30I**, P-2.065 (2006)*

Nano-phase network and nano-composite structure of FeCo synthesized using plasma focus

T. Zhang, S. Mahmmod, J. Lin, S.M. Hassan, T.L. Tan, S. V. Springham, P. Lee, and R.S. Rawat

Natural Sciences and Science Education, National Institute of Education, Nanyang Technological University, Singapore 637616

Abstract

We report the synthesize FeCo nano-phase particles or thin film using plasma focus (PF) device, in two different ways: (a) a conventional way, using a FeCo tip fitted copper anode which is ablated by hot plasma and energetic electron beam and (b) by the ablation of FeCo target using extracted electron beam in a specially designed chamber attached to the lower end of PF device. When the conventional way is used, the samples with 25 shots or less show a uniform FeCo thin film. The agglomerates with size of 100 nm are composed of smaller grains of the size approximately about 20-30 nm. When the number of focus shots was increased, a different surface morphology is observed. The surface of the sample has a complex distribution of nano-phase network structure. For electron beam ablation deposition in lower chamber, smaller nano-particles were found on the surface of the samples and network structures were not observed. The TEM analysis of both types of samples shows that different grains have different crystalline planes with intermediate amorphous structure.

I. INTRODUCTION

The current curiosity on nano-particles has been phenomenally increasing because of their interesting electronic, optical, magnetic, mechanical and chemical properties [1]. The metallic nano-particles of magnetic materials are of special interest owing to their notable uses and applications in ultrahigh density data storage, gas sensor, toner material for high quality color copier and printer, new generation electric motor and generator, environment friendly refrigerants and biomedicine [1-2]. Each of the applications requires the magnetic nano-particles to have different properties [2]. Hence, the synthesis of magnetic nano-particles in a controlled manner is still a real challenge for their practical usages. Molecular beam epitaxy, triode sputtering, ultrasound-assisted electrochemistry, dc magnetron

sputtering, laser ablation and e-beam have been used to deposit magnetic particles and magnetic thin films [3-5].

Compared with these methods, plasma focus, as a copious source of energetic ions and electrons, has advantages such as high deposition rate, energetic deposition process and possible deposition under a reactive background gas pressures. The deposition process in dense plasma focus (DPF) is done through the heating, compressing and ionizing the filling gas to form plasma. The plasma then disintegrated due to plasma instabilities which generate energetic ions and relativistic electrons. They are responsible for the ablation of the anode material and the ablated material is deposited on the substrate. We have recently reported the successful synthesis of Fe and FeCo nanoparticles using single shot UNU-ICTP 3.3 kJ plasma focus [6,7]. In our present investigation, a repetitive plasma focus machine NX2 was used to synthesize FeCo magnetic nano-particles and nano-phase network structured material.

II. EXPERIMENTAL SETUP

In our investigation, a repetitive plasma focus machine designated as NX2 was employed to deposit FeCo samples. FeCo samples were prepared using two different ways: (a) in a conventional way, by replacing the usually used copper anode with a FeCo fitted anode and then depositing the ablated FeCo plasma, on Si substrate placed up the anode axis, the distance between FeCo sample and Si substrate is 25 cm, and (b) by the ablation of FeCo target disc, in a specially designed chamber attached to the lower end of plasma focus device, with the use of extracted electron beam. The DPF device was operated different shots at a charging voltage of 12 kV with hydrogen as the filling gas at a pressure of 12 mbar. Silicon wafer, working as the substrate, is cut into smaller dimensions of 10mm × 10mm × 0.68 mm and then washed by soaking into acetone, alcohol and de-ionized water respectively for durations of 5 minutes in an ultrasonic bath. The morphology and crystalline characteristics of the samples prepared using two methods were analyzed and compared using Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

III. RESULTS & CONCLUSION

Fig. 1 shows the SEM and TEM results when the conventional synthesis method was used. From the topography of the samples, we can see that for low numbers of deposition shots (25 shots), FeCo thin film was quite uniform and composed of agglomerates with size around 100nm. The agglomerates are made up of smaller grains with size of 20-30 nm. Increasing the deposition shots, uniform but different nano-structures are observed (shown as 100 shots). It looks like that network of nano-structure is growing on the agglomerates, i.e.

with the increase in number of shots, a network structure is precipitating with agglomerates, that are deposited during first tens of shots, forming a background. The particles in network are of smaller sizes, typically around 10nm. According to our observations, we can conclude that during initial focus shots the particle-agglomerates of size of about 80-100 nm (composed of grains of 20-30 nm) are deposited on the substrate, however, once this layer is formed, the increase in number of focus shots increases the size of the particle-agglomerates and also promotes linear nano-structure (kind of beaded-nanowire) formation on the surface.

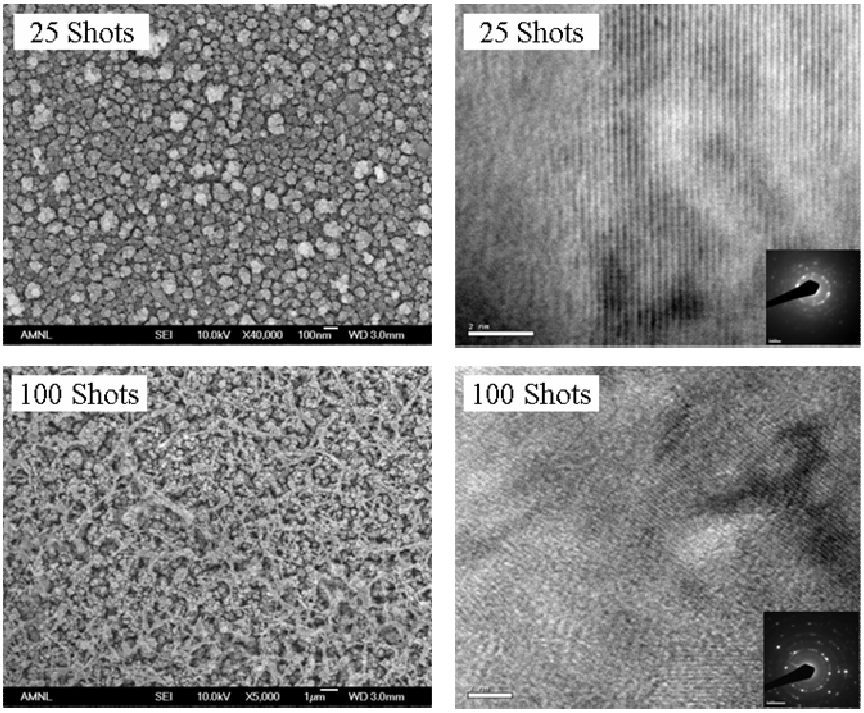

Fig. 1 SEM and TEM results for 25 and 100 shot deposition.

When TEM was used, the top of the FeCo nano-particles thin film was found about 20-30 nm, which matches well with to the observations of Scanning Electron Microscopy. When higher magnification of the FeCo thin film to 2 nm resolutions was used, the crystal planes of the thin film can be observed. It is found that particles at different positions have different crystal plane directions. In between amorphous structure was observed. The diffraction pattern shows that particle observed is FeCo.

Fig. 2 presents the SEM results of FeCo thin film using electron beams for 100 and 250 shots. For 100 shots, the surface shows a mixture of particle-agglomerates. The particle-agglomerates, with the size varying from 50-200 nm, are also composed of smaller grains (with grain size of 20-30 nm). With the increase in number of deposition shots, the structure similar to 100 deposition shots was observed but with the much different bigger and dense