High density gas aggregation nanoparticle gun applied to the production of SmCo clusters

G. T. Landi, A. D. Santos, S. A. Romero, and A. Y. Hirata

Laboratório de Materiais Magnéticos, Instituto de Física da Universidade de São Paulo, São Paulo, SP, Brasil

Abstract: We present the development of a gas aggregation nanoparticle gun based on a magnetron sputtering system capable of producing high volumes of material of any metallic element or alloy desired with controllable size distribution. Furthermore, through auxiliary sputtering guns, it is possible to embed the particles on dielectric and metallic matrixes or multi-layers. We also present the morphological, structural and magnetic properties of high coercivity SmCo nanoparticles produced by our system.

Gas aggregation cluster production methods have seen increasing attention on recent years due to the precise control over the size and stoichiometry of the sample. Also, since the clusters are grown in vacuum on a multi-gun chamber, protection against corrosion and matrix co-deposition are also feasible. Although there are no restrictions as to the amount of material produced, most of these methods have low deposition rates making them suited mostly to investigate surface phenomena and other small scale properties. In this presentation we describe a gas aggregation nanoparticle gun capable of producing high volumes of material very quickly. With it we are able to produce thick samples in small amounts of time and, if desired, to precisely control the thickness.

The magnetron sputtering system in which the cluster gun was produced is a commercial (AJA 2000 international) 4-gun high vacuum system. The cluster gun consists of a 10 cm in diameter ,15 cm long, cylindrical chamber inserted over one of the sputtering guns. This chamber is completely sealed, except for a 2 mm aperture on its frontal end (figure 1). Using a concentrated argon flux inserted near the sputtering target we are able to create a high pressure region inside the condensation chamber. This pressure thermalizes the atomic vapor thus condensing them into clusters. Unlike usual systems, the exceptionally high pressures we apply cannot be used as a direct parameter to control the particles sizes. The power applied to the target is the main variable used to change the clusters dimensions.

With the high pressure inside the condensation chamber and the significantly lower pressure of the main sputtering chamber (determined by the vacuum system), there is also a high pressure gradient between the two chambers mediated by the aperture. This results in a expressive collimation of the argon flux, specially in the regions near the aperture. With this collimation, the atomic vapor and clusters, which are initially directed on a wide solid angle from the target, have their trajectories altered by the gas flux. The result is an extremely efficient collimation of the material. After they are removed from the aperture, they expand aerodynamically into a high density beam of particles which are then deposited onto a substrate place a few centimeters away from the aperture. Using Rutherford backscattering we have estimated the deposition rate for samples with 30 W of power and 85 sccm of flux. We obtained values as high as 75 nm/min on the center of the substrate, or namely 1 layer of particles every 8 seconds for 10 nm particles. These values, already 10 fold higher than many systems, may be further increased just by increasing the power applied to the target. Away from the center, the deposition rate decreases following a Gaussian distribution.

Figure 2 shows scanning electron microscopy (SEM) images of SmCo nanoparticles of two different sizes: 10 nm and 20 nm. These sizes were roughly estimated using transmission electron microscopy and X ray diffraction. Figure 3 depicts the difference in crystal structure of both samples where only the 20 nm show a good crystallinity. Finally, figure 4 shows hysteresis loops of both samples measured using a vibrating sample magnetometer. It can be seen that the coercivity of the 20 nm sample is significantly higher with the out of plane curve being asymmetric, which shows that the sample isn't completely saturated, an evidence of high magnetic anisotropy. This happened because the sample was produced with a strong magnetic field applied perpendicular to the substrate.

[1] G.T. Landi, S. A. Romero and A. D. Santos. To be submitted to *Review of Scientific Instruments*

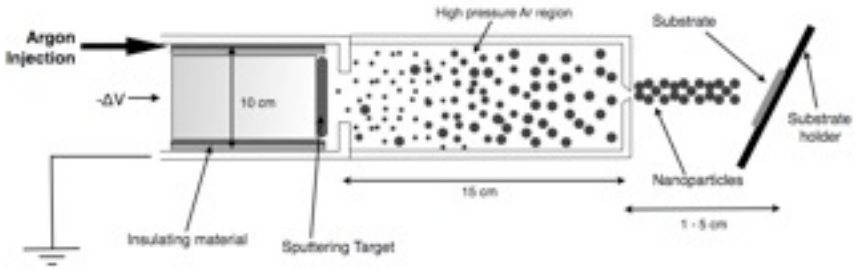

Figure 1: *schematic view of the nanoparticle gun.*

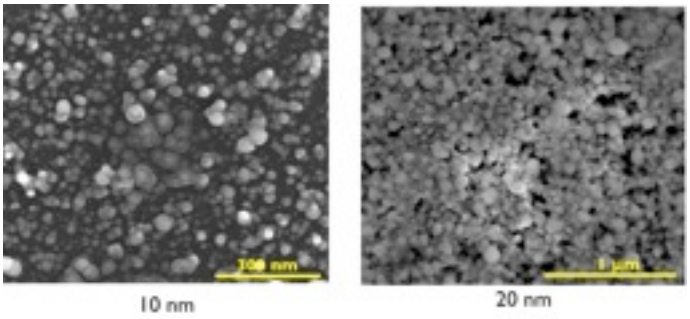

Figure 2: *SEM images of SmCo nanoparticles with 10 and 20 nm mean diameter.*

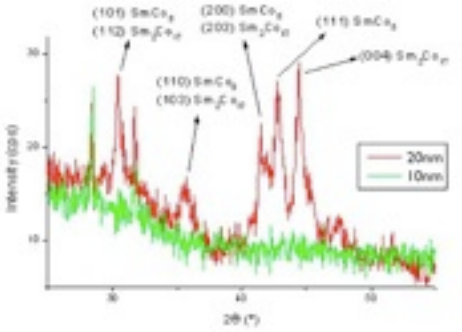

Figure 3: *XRD patterns of 10 nm and 20 nm SmCo nanoparticles and corresponding phase peaks.*

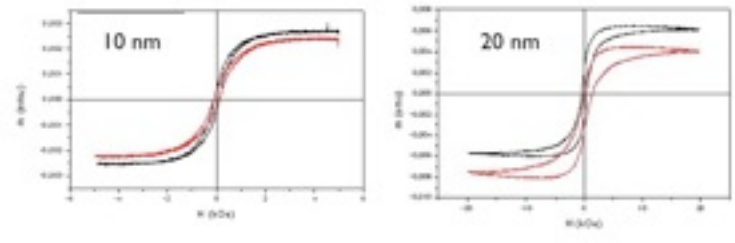

Figure 4: *in (red) and out (black) of plane hysteresis loops for the 10 and 20 nm SmCo nanoparticles.*