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Ion Beam Sputter Deposition of Low Work Function and GMR Materials

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Abstract:
Ion beam Sputter deposition (IBSD) has been under development for a number of years due to the flexibility it provides in the deposition of novel thin film materials. One of the unique characteristics of IBSD is the ability to deposit multicomponent or multilayered materials using a multi-target single ion gun scheme. This is accomplished by sequentially positioning selected targets, which are mounted on a multi-target wheel, in front of the ion gun. Alternating layers as thin as 10 Angstroms have been deposited using this approach. When the deposition is done in a reactive environment compound materials are produced. The use of IBSD for the deposition of low work function compounds and multilayered metals which exhibit giant magnetoresistance will be described. The characterization of these materials will be discussed.

1. Introduction

Sputtering is one of the most widely established techniques for depositing thin films for a wide variety of applications. It's widespread acceptance is due to the uniformity and reproducibility of the deposited films, the high sputter rates, and the fact that any material that can be shaped into a target can be sputtered. Conventional RF and DC sputtering have limitations[1]. During sputtering the substrate is in contact with the plasma which is generated in order to produce ions of the inert working gas. Being in contact with the plasma may cause the substrate temperature to rise to as high as 200 °C. In order to sustain the plasma, the pressure must be in the millitorr range. As a result, volatile impurities and the sputtering gas may be incorporated in the growing film.

2. Results and discussion

Ion beam sputter deposition (IBSD) offers the advantages of conventional sputtering while operating at a lower pressure[2]. A low operating pressure minimizes the problem of substrate heating and gaseous impurity incorporation in the growing film. Figure 1 is a schematic drawing of the IBSD system developed at MCNC. The base pressure of the system is 10^{-9} Torr. It utilizes an RF ion source from Ion Tech, Inc. Although, the pressure inside the ion source is in the range of 10^{-2} Torr, the pressure inside the deposition chamber does not rise above 10^{-4} Torr. Up to four sputtering targets are mounted on a computer controlled carrousel which allows them to be rotated sequentially into position in front of the ion source. Films as thin as 10Å may be deposited from each target. The sputtering targets rotate on an axis perpendicular to the surface to minimize the development of surface topography on the target after extended use. The flux of sputtered ions intersects with the target. The target also rotates on an axis perpendicular to the surface to improve the film uniformity. The sputter deposition target may be tilted. This helps to minimize the probability that scattered neutrals will impact the growing film. These energetic neutrals cause forward scattering and mixing which broadens the interface boundary between layers.

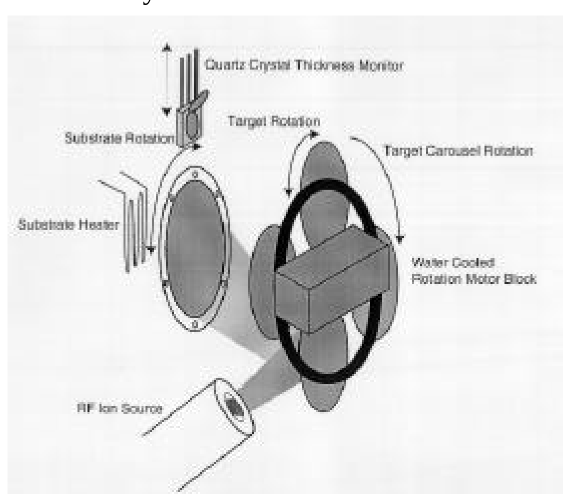

Fig. 1 Ion Beam Deposition System

Control of the interface uniformity and sharpness is critical to the giant magneto-resistance (GMR) effect which occurs in ultrathin multilayer stacks consisting of alternate layers of a ferromagnetic metal separated by layers of a non-ferromagnetic metal[3].

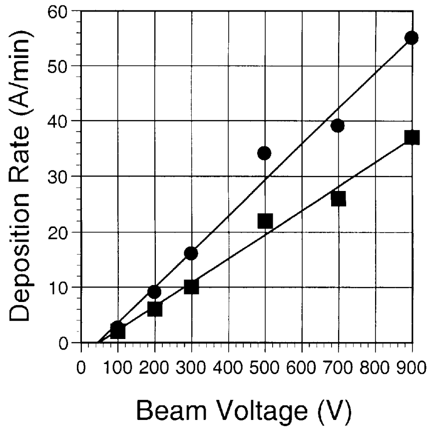

Fig. 2 The dependence of the deposition rate for Cr ( ) and Fe (l) films on the beam voltage. Argon was used as the ion source gas, and the ion beam current, measured at the grid of the ion source, was 35 mA.

alternating layers. IBSD has shown great promise for the controlled deposition of these metals. Figure 2 shows the film thickness as a function of time of the sputter deposition of Fe and Cr. The deposition rate is low so that greater control over the film thickness can be achieved.

Figure 3 shows a cross-sectional transmission electron microscopy (TEM) micrograph of a Si/Cr/(Fe/Cr) (x10) stack deposited by IBSD. The contrast between Fe and Cr is enhanced by defocusing the image. The micrograph shows that the interfaces between layers are planar and smooth, with consistent quality across the stack. Lines are drawn to help aid the eye in distinguishing these layers.

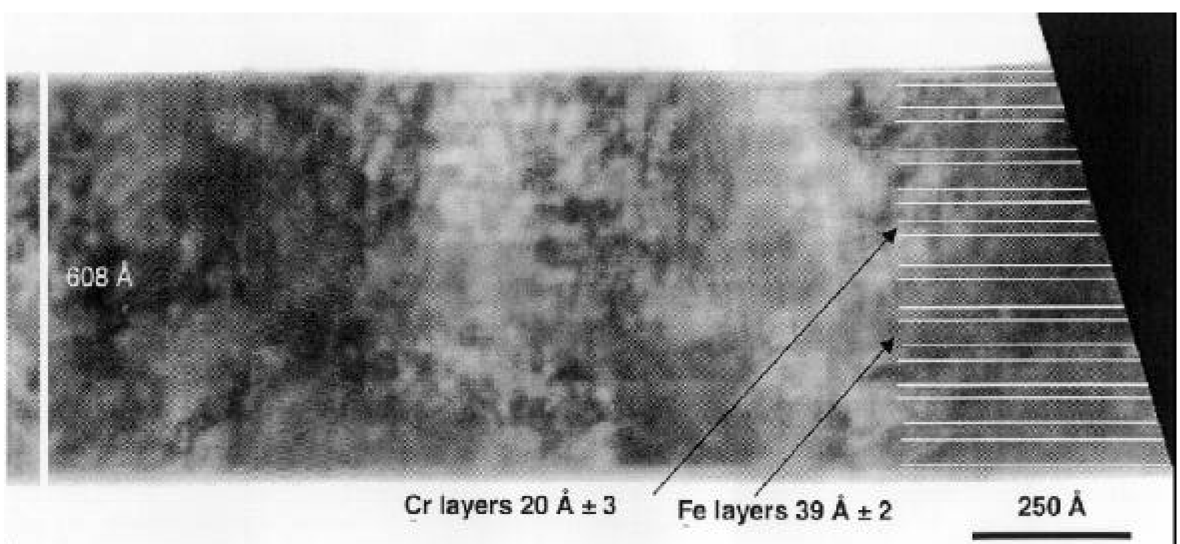

Fig. 3. A TEM micrograph of a Si/Cr/(F/Cr)x 10 multilayer deposition by the IBSD technique.

The GMR effect typically increases as the thickness of the non-ferromagnetic layer decreases. Continuity of the film is believed to be important as well as interface roughness which contributes to electron scattering. Uniformity must be maintained for 10 or more

3. Conclusions

An IBSD system has been constructed with a low base pressure which allows the computer controlled deposition of multiple layers of alternating materials with excellent film smoothness and interface uniformity. Among the first materials explored were metals which were deposited in films as thin as 10Å with a view toward application as GMR materials. Initial magnetic measurements of IBSD deposited (Fe/Cr)(x10)Si films revealed GMR ratios comparable to the best values in the literature for similar film thickness.

References

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2. J.M.E. Harper in “Thin Film Processes”, Academic Press, Inc., 1978, p. 175.

3. R.L. White, “Giant Magnetoresitence: A Primer”, IEEE Trans. On Magn. 28(1992)2482.