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Fabrication and Characterization of Ferromagnetic-Superconducting Hybrid Films Grown by Combined PVD Techniques

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ABSTRACT

This study reports micro fabricated magnet and superconductor (permalloy/$Pb_{82}Bi_{18}$) hybrid film structures sequentially grown by magnetron sputtering and thermal deposition techniques. 300 nm thick PbBi film was quench condensed on top of a patterned permalloy film. Permalloy film was sputtered and patterned to form few micrometer-wide stripes. Ferromagnetic and superconducting layers were separated by Al_2O_3 insulation. Transport Superconducting properties i.e. transition temperature $T_C(H)$ and second critical field $H_{C2}(T)$ were measured in a range of applied magnetic field between H=0 and H=7 kOe for the hybrid system and a control sample with only a layer of superconducting film deposited. The $H_{C2}(T)$ data showed that due to the interplay between the superconducting film and the ferromagnet, superconducting (SC) and normal current paths formed on the SC film.

1. Introduction

In the science and applications of thin-films, the magnetism and superconductivity are known to be great examples of mutually exclusive states. However, as reported in [1- 4], when combined in micro / nano scale the interplay between the stray field from the magnetic structures and the superconductor leads to exotic superconducting characteristics.

Several magnet-superconductor hybrid systems were studied theoretically [6, 7] and experimentally [8 - 11] in recent years. Lyuksyutov and Naugle predicted that magnetic rods embedded into a superconductor can increase $H_{C2}(T)$ [16], and they also previously predicted vortex pinning enhancement by magnetic defects in magnet-superconductor hybrids [16, 17]. More information on magnet-superconductor bilayer hybrids can be found in reviews [12 - 15]. The length scale of magnetic field inhomogeneity in all these works is in the micrometer range. Also typical for most magnet-superconductor hybrids studied, the second critical field $H_{C2}(T)$ is shifted higher with respect to a control superconducting system [11, 13 - 15]. In all of these studies coercive magnetic materials such as Fe, Ni and Co were used to grow the magnetic structures. To this date, hybrids with ferromagnetic substructures fabricated from softer magnetic alloys such as permalloy showing similar behavior of $H_{C2}(T)$ has not yet been reported.

2. Fabrication

Two distinct Physical Vapor Deposition (PVD) techniques have been used for the fabrication of magnet-superconductor hybrid films. A schematic cross-sectional view of PbBi-permalloy