CuNi/Nb S-F Hybrid Heterostructures for Investigation of Induced Magnetization in Superconducting Layer

Yu. KHAYDUKOV[1], J.-H. KIM[1], G. LOGVENOV[1], R. MORARI[2], E. BABAKOVA[2], A. SIDORENKO[2]

[1]*Max-Planck-Institut für Festkörperforschung, D 70569 Stuttgart, Germany*

[2] *Institute of Electronic Engineering and Nanotechnologies ASM, MD2028, Kishinev, Moldova*

***Abstract* — The mutual influence of the magnetism and superconductivity in superconductor/ferromagnet (S/F) nanofabricated thin films hybrid heterostructures has been an exciting topic in solid-state physics during last decade (see, e.g. review [1]). However, the interesting theoretical predictions still wait for unambiguous experimental verification. One of such effect is the so-called spin screening (often called inverse proximity effect), which designates a spin polarization in the superconducting layer close to the S/F interface. It is theoretically shown [2, 3] that a spin polarization develops in the S layer with direction opposite to the spin polarization of the conduction electrons in the F layer. If the thicknesses of the ferromagnetic and superconducting layers are small compared to the London penetration length, then the orbital effect, caused by Meissner screening currents of superconductor will be small compared to the spin effect due to spin polarization. The thickness of the spin polarized sub-layer is comparable to the coherence length ξ of the superconductor. Therefore an advanced technology should be used for fabrication of S/F nanostructures with thin superconducting layers.**

***Index Terms* — hetero-structures, ultra-thin films, superconductivity, magnetism, proximity effect, inverse proximity effect.**

I. MAGNETRON SPUTTERING

Samples were prepared in the magnetron vacuum installation Leybold Z-400 on Si substrates at room temperature. Sputtering was performed under an Argon (99.999%, “Messer Griesheim”) atmosphere of 8×10-3 mbar with a residual pressure in the chamber of about 1.5×10-6 mbar. The commercially available silicon wafer with (1 1 1) crystalline orientation was chosen as a substrate. In total tree different targets were used: superconducting niobium (Nb) with a purity of 99.99%, silicon (Si) with purity of 99.99% (for buffer and protecting layers) and ferromagnetic copper-nickel alloy (60% Ni -40% Cu).

In order to remove any contaminations, as absorbed gases and oxides, the targets were pre-sputtered for 3-5 minutes before the deposition of the S/F-structures. The deposition rate of the layers was: for Nb – 4,5 nm/s, for CuNi alloy – 3,5 nm/s, for Si – 1 nm/s.

S/F-sample was prepared as following: Si(buffer, 5 nm)/Nb(7.2 nm)/CuNi(3 nm)/Si(cap, 5 nm). The first thin film of amorphous silicon has been sputtered on the top of the substrate in order to achieve a homogenous and flat surface. The ferromagnetic CuNi alloy has been grown above the superconducting Nb layer. As a final step, 5-nm thick Si layer has been deposited onto the top of the S/F heterostructure to prevent it from oxidation.

II. SAMPLES CHARACTERIZATION

Structural properties of the samples have been checked by the low angle Θ-2Θ X-ray diffraction (X-ray reflectivity). The reflectivity data of the S/F-sample is showed in Fig. 1. The curve is characterized by the presence of the total reflection plateau and Kiessig oscillations with period $\Delta Q \cong 0.6$ nm^{-1}. Oscillations are caused by the interference on a layer with thickness $d = 2\pi/\Delta Q \cong$ 10-11nm. Since the X-ray scattering length density of Nb (6.38x10^{-5} Å^{-2}) and CuNi (6.44x10^{-5} Å^{-2}) are close to each other, X-ray reflectivity is sensitive to the total thickness of CuNi and Nb layers. The estimated thickness d = 10-11nm is pritty close to the nominal thickness of the S/F bilayer, calculated from the deposition time and the deposition rate.

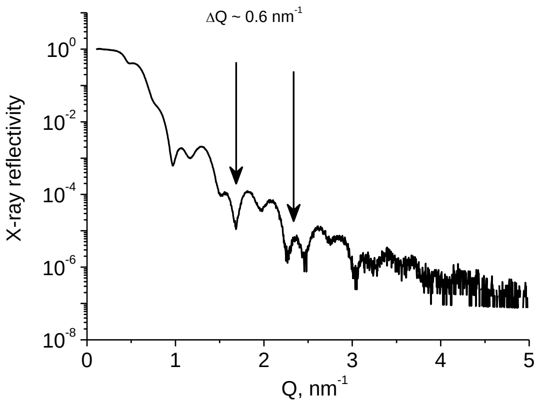

Figure 1. X-ray Reflectivity of the Nb(7.2 nm)/CuNi(3 nm) hybrid heterostructure.

Magnetic and superconducting properties of the bilayer were characterized by the Quantum Design MPMS SQUID VSM magnetometer. The magnetic hysteresis loop was measured at T = 15K (far above

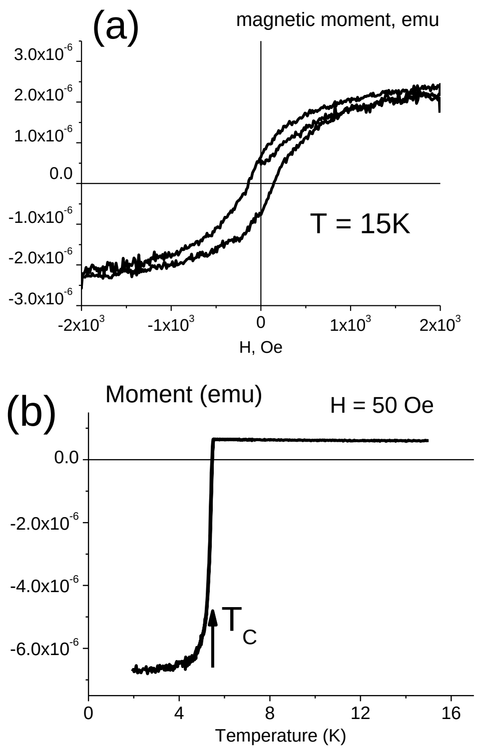

Fig. 2. (a) SQUID magnetization hysteresis loop at 15 K. The magnetic field was applied in-plane. (b) Field cooled (FC) SQUID magnetization versus temperature for the S/F hybrid heterostructure with total thickness of superconducting Nb and ferromagnetic CuNi layers ~10.9 nm. (The external magnetic field 50 Oe was applied in-plane). The arrow shows the superconducting transition.

superconducting transition temperature of bulk Nb) with magnetic field applied parallel to the sample surface. Measurement have demonstrated that the CuNi layer is a hard ferromagnet with saturation magnetization at $H_{sat} \approx$ 1kGs.

Temperature dependence of the magnetic moment measured at magnetic field H = 50 Oe applied parallel to the sample surface allowed to define superconducting transition temperature of Nb (7.2nm) layer T_C = 5.4K which is close to the value of similar Nb/NiCu structure reported earlier [4].

CONCLUSION

Overall we have prepared high quality S/F CuNi/Nb hybrid heterostructures which are suitable for further investigation of the induced magnetization in the superconducting Nb layer.

REFERENCES

[1] Bergeret F. S., Volkov A. V. and Efetov K. B., Rev. Mod. Phys.77, 1321 (2005).
[2] Bergeret F. S., Volkov A. V. and Efetov K. B., Phys. Rev. B 69, 174504 (2004).
[3] Kharitonov M. Yu., Volkov A. V. and Efetov K. B., Phys. Rev. B 73, 054511 (2006).
[4] Zdravkov V., Sidorenko A., Obermeier G. et al., Phys. Rev. Let. 97, 057004 (2006)