SUPERCONDUCTING SPIN – SWITCH FOR SPINTRONICS

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Abstract. *Very rapid developing area of spintronics needs new devices, based on new physical principles. One of such devices – a superconducting spin-switch consists of ferromagnetic and superconducting layers.The thicknesses tuning of superconducting and ferromagnet layers is investigated to optimize superconducting spin-switch effect for Nb/$Cu_{41}Ni_{59}$ based nanoscale layered system.*

Key-Words: *spintronics, spin-switch, layered system, proximity effect.*

I. Introduction

Superconducting spin-switch based on proximity effect in Ferromagnet – Superconductor – Ferromagnet layered system (F/S/F) was analysed theoretically in [1] using hypothetical materials and its thicknesses. Several experimental attempts [2-10] demonstrated existence of spin-switch effect but it's value should be increased for real technical applications. Some of experimental studies of F/S/F stuctures have shown the normal spin – switch effect with maximium shift $\Delta T_c \approx 41$ mK of superconducting critical temperature for parallel and anti-parallel allighnement of the ferromagnetic layers magnetization, other experiments revealed the "inverse" spin – switch effect with $T_c^P > T_c^{AP} (\Delta T_C < 0)$. We present calculations of spin-switch effect for Nb as superconductor and $Cu_{41}Ni_{59}$ alloy as ferromagnet layer which was used to detect re-entrant superconductivity [11] and discuss some technological and experimental approaches, which may be used for a superconducting spin-switch design.

II. Nanostructures deposition and characterization

We developed a special advanced technological process of superconducting layers preparation for reliable fabrication of S/F structures with the layer thickness scale of several nanometers [12]. The S and F layers were deposited by magnetron sputtering on commercial (111) silicon substrates at room temperature. The base pressure in the "Leybold Z400" vacuum system was about 2×10^{-6} mbar. Pure argon (99.999%, "Messer Griesheim") at a pressure of 8×10^{-3} mbar was used as sputter gas. A silicon buffer layer was deposited using RF magnetron. It produced a clean interface for the subsequently deposited niobium layer. To obtain flat and high-quality Nb layers with thickness in the range of 5-15 nm, the rotation of the target around the symmetry axis of the vacuum chamber was realized. A dc-motor drive moved the full-power operating magnetron along the silicone substrate of the 80×7 mm^2 size during the deposition. Thus, the surface was homogeneously sprayed with the sputtered material. The constructed deposition mashine is patented. The effective growth rate of the Nb film in this case was about 1.3 nm/sec. The deposition rate for a fixed, non-moving target would be about 4-5 nm/sec. The next step of the procedure was deposition of a wedge-shaped ferromagnetic layer utilizing the intrinsic spatial gradient of the deposition rate of the sputtering material. The $Cu_{40}Ni_{60}$ target was RF sputtered with a rate of 3-4 nm/sec, resulting in practically the same composition ($Cu_{41}Ni_{59}$) of the alloy in the film. To prevent a destructive influence by the atmospheric conditions, the last deposited layers were coated by a silicon cap of about 5-10 nm thickness (a sketch of the prepared samples – core sructures for design of the superconducting spin-switch is shown in Fig. 1).

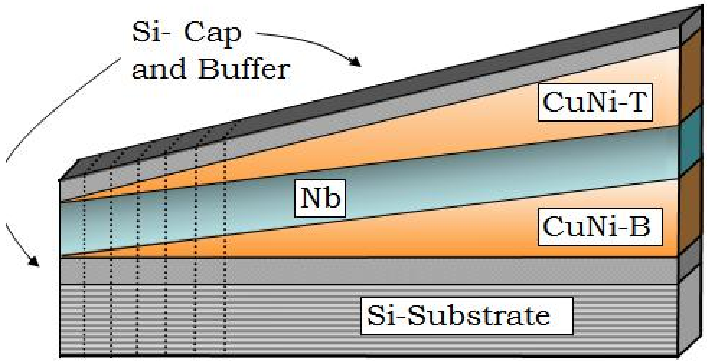

Fig.1. Sketch of the layers stack in the deposited F/S/F-core structure of the spin-switch.

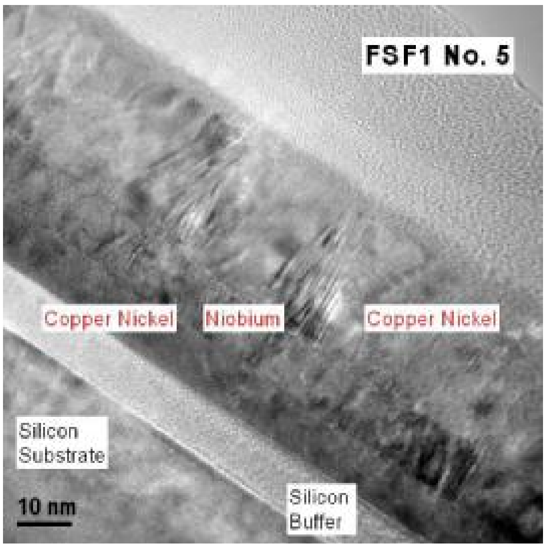

Fig.2. Cross sectional TEM image of a F/S/F 3-layer structure (CuNi/Nb/CuNi)

The Transmittion Electron Microscop image of the prepared core-structure is shown in Fig.2, demostrating the highest quality of the interfaces between the layers niobium/copper-nickel, that makes it possible to use such 3-layer structures for the spin-switch construction.

III. Calculation and discussion

We used calculation procedure described in [12] with the parameters close to extracted from [11].

The results for superconducting critical temperature T_c for parallel and anti-parallel directions of ferromagnet layers magnetizations with superconducting Nb thicknesses 12.5nm, 14 nm are presented in Fig.3.

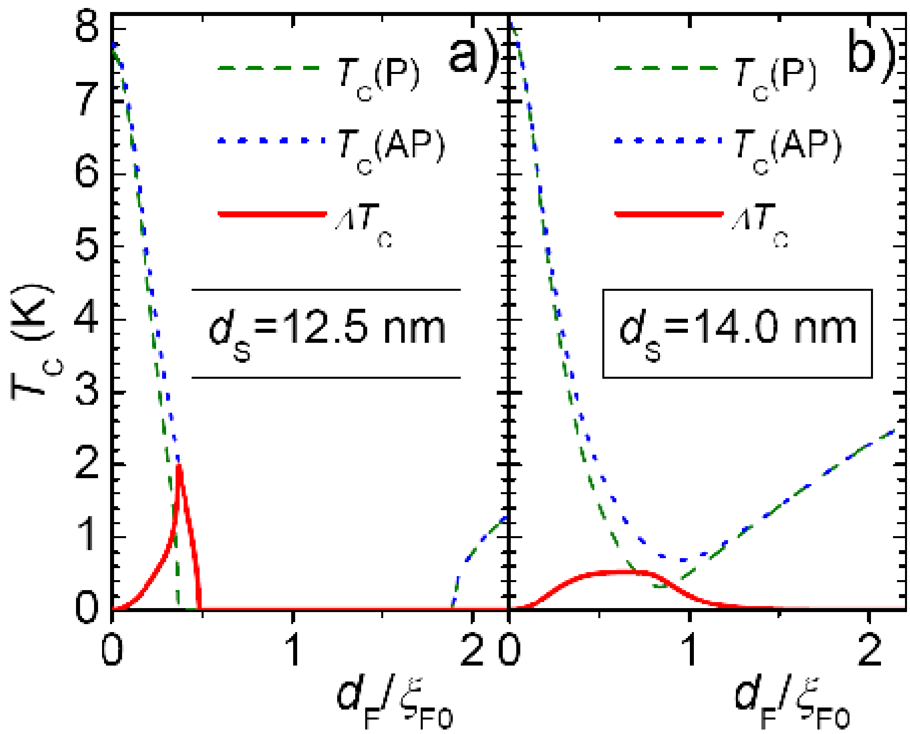

Fig.3. The $T_c(d_F)$ curves of a superconducting F/S/F spin-switch core structure with $d_S = d_{Nb}$= 12.5 nm (a), $d_S = d_{Nb}$= 14 nm (b) calculated using the following set of parameters for (a) and (b) respectively: $T_{c0,Nb}(d_{CuNi} = 0$ nm) = 7.7, 8.1 K; in all cases ξ_S = 6.6 nm; $N_F v_F/N_S v_S$ = 0.22; T_F = 0.6; l_F/ξ_{F0} = 1.1; ξ_{F0} = 10.5 nm.

One can see that maximal spin-switch effect value ΔT_c with the order of 1-2 K is achievable only in very strict region of superconductor and ferromagnet layer thicknesses. Otherwise one can expect only negligible value of ΔT_c with order of 10^{-3}K what was detected in experimental works mentioned above [2-10].

IV. Conclusions

It was developed advanced vacuum technology of nanostructures preparation applicable for design of spintronic devices. Based on the experimental parameters it is found, that maximal spin-switch effect value with the order of magnitude of 1-2 K is achievable for the strict range of superconductor and ferromagnetic layers thicknesses in the re-entrance region of the superconducting transitions. This range of controlled thicknesses is accessible for preparation of the F/S/F-core structure for a superconducting spin-switch construction.

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VI. References

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