Nb-PtNi-Nb Josephson Junctions Made by 3D FIB Nano-Sculpturing

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1. Motivation

Hybrid SFS devices put strong constrains on the F-layer: technologically the F-layer should be thick enough, ~20 nm, to form a uniform Josephson barrier without pin-holes. This in turn requires that the F-layer is made of a weak, diluted F-alloy, to allow a significant supercurrent. Even more requirements are imposed on spin-valve devices, which require monodomain F-components with uniform spin polarization. This can only be achieved by decreasing the size of the F-layers and by using the shape anisotropy. However, this puts strong demands on the nano-scale spatial homogeneity of the F-alloys. Another reason for decreasing the total area of SFS junctions is a very small resistance per unit area, which require SQUID measurements.

2. Sample fabrication

1. Sputtering of Nb-PtNi-Nb-PtNi multilayer, 2. Spin coating with positive photoresist, 3. Exposure with UV light, 4. Development, 5. Ar\textsuperscript{+} milling of upper Pt layer, 6. CF\textsubscript{4}, RIE etching of upper Nb layer, 7. Ar\textsuperscript{+} milling of lower Pt layer 8. CF\textsubscript{4} RIE etching of lower Nb layer, 9. Removal of residual photoresist.

FIB image of the junction. (a) top view and (b) side view. The insets show schematic and position of the sample holder at which top and side cuts are made (right of (a) and (b) respectively) and top and side views of the structure (left of (a) and (b) respectively).

3. Characterization of PtNi thin films

(a) normalized Hall resistance ($R_{H}/H$) versus $T$ for different Ni-concentrations ($R_{H}/HT$) are Hall resistances for positive and negative field directions. $R_{H}/H$ at 4.2K and $T_{c}$ as a function of Ni-concentration and (c) Hall resistance versus magnetic field for Ni-concentrations corresponding to 10 and 30 % of Ni-target area.

4. Characterization of Nb-PtNi-Nb junctions

(a) dependence of the junction critical current ($I_{c}$) on in-plane magnetic field across the size of length 1140 nm. The inset of (a) shows current-voltage characteristic of the same junction. (b) junction critical current density ($J_{c}$) versus temperature ($T$) (in the semi-logarithmic scale) for different Ni-concentrations. (c) dependence of the coherent length on inverse $T$ and (d) $J_{c}$ as a function of $T$-concentration. The inset of (d) shows $J_{c}$ versus PtNi thickness.

Conclusions

We fabricated nano-scale SFS Nb-PtNi-Nb junctions with sizes down to ~70\textsuperslash{}80 nm\textsuperslash{}2. EDS analysis indicated that the employed diluted PtNi ferromagnetic layer is characterized by excellent homogeneity at the nm scale. Therefore, such junctions may be promising for hybrid S/F spin-valve devices, which require small, mono-domain F-barriers.