Nanoscale devices fabricated by focused ion beam irradiation of $YBa_2Cu_3O_7$ thin films

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Recent advances in focused ion beam (FIB) techniques have opened new opportunities for nanoscale milling and local modification of thin film superconductors. We present various FIB-based approaches to produce devices in thin films of the cuprate superconductor $YBa_2Cu_3O_7$ (YBCO). By Ga FIB milling, we fabricated YBCO nanoSQUIDs on bicrystal substrates with ultra-low flux noise in the thermal white noise limit [1]. Such devices offer detection of magnetization reversal processes in individual magnetic nanoparticles or nanowires [1-3]. By He FIB irradiation, it is possible to locally drive YBCO from the superconducting to the insulating state, with high spatial resolution, and hence to "write" Josephson barriers into thin films [4]. We present here a comprehensive analysis of the electric transport properties at 4.2 K of He-FIB produced YBCO Josephson junctions [5]. The critical current density j_c can be adjusted by irradiation dose D, with an exponential decay of $j_c(D)$. A transition from flux-flow to Josephson behavior occurs when j_c decreases below ~2 MA/cm^2. For Josephson devices we find an approximate scaling of the characteristic voltage $V_c \propto j_c^{1/2}$, and current-voltage characteristics that are well described by the resistively and capacitively shunted junction model, without excess currents for $V_c < 1$ mV. The He-FIB technique provides the possibility to place junctions at arbitrary location, with different orientation and shape, and even with different j_c on the same chip. Moreover, He-FIB irradiation with high dose produces highly resistive walls or areas. We used this feature to produce dc SQUIDs with sub-µm loop sizes and very low flux noise. Altogether, the He-FIB technique provides a promising tool for nanoscale patterning of advanced devices, e.g. Josephson junction arrays, in YBCO thin films.

References

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