Focused Helium Ion Beam Irradiated Josephson Junctions and Arrays

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We have fabricated Josephson junctions and arrays with a focused helium ion beam from Y-Ba-Cu-O, a high temperature superconductor.[1] The Josephson junction is the fundamental building block of most superconducting electronics. Normally the size of a junction is chosen to be less than the Josephson penetration depth (λ_J) ~4 μm, a fundamental length scale for superconducting devices, because it ensures that the supercurrent is distributed evenly throughout the junction. For a static current biased Josephson junction or array of junctions, the voltage across the device modulates in a magnetic field. The voltage as a function of magnetic field (*V-B*) of an ideal Josephson junction goes as $|\sin(B\times A)/(B\times A)|$.Where $B\times A$ is the product of applied magnetic field *B* and junction area, *A*. When the length of a junction becomes larger than λ_J, the *V-B* comes more triangular and asymmetric as shown in figure 1.[2] As a result, this improves the linearity of the Josephson based voltage magnectic field transducing devices. In addition, the skewing of the *V-B* makes one side of the peak extremely sharp that enhances the sensitivity (d*V*/d*B*) to detect small fields..

In our work, we will present the fabrication process and measurement results of Josephson junctions and arrays with widths that range from 1 micron to 30 microns. These devices were fabricated with 30 nm Y-Ba-Cu-O films grown by reactive coevaporation. After patterning the large features and electrodes of the devices with standard photolithography and Ar ion beam etching, the junctions were directly written using a 30 keV focused helium ion microscope with doses of 10^{16}~10^{17} ions/cm^2. Our results show that Josephson junctions and arrays have great potential for large dynamic range for advanced magnetic antennas for communications.

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[1] Cybart, S.A., Cho, E.Y., Wong, T.J., Wehlin, B.H., Ma, M.K., Huynh, C. and Dynes, R.C., 2015. Nano Josephson superconducting tunnel junctions in YBa2Cu3O7–δ directly patterned with a focused helium ion beam. *Nature nanotechnology*, *10*(7), pp.598-602.
[2] Basavaiah, S. and Broom, R., 1975. Characteristics of in-line Josephson tunneling gates. *IEEE Transactions on Magnetics*, *11*(2), pp.759-762.

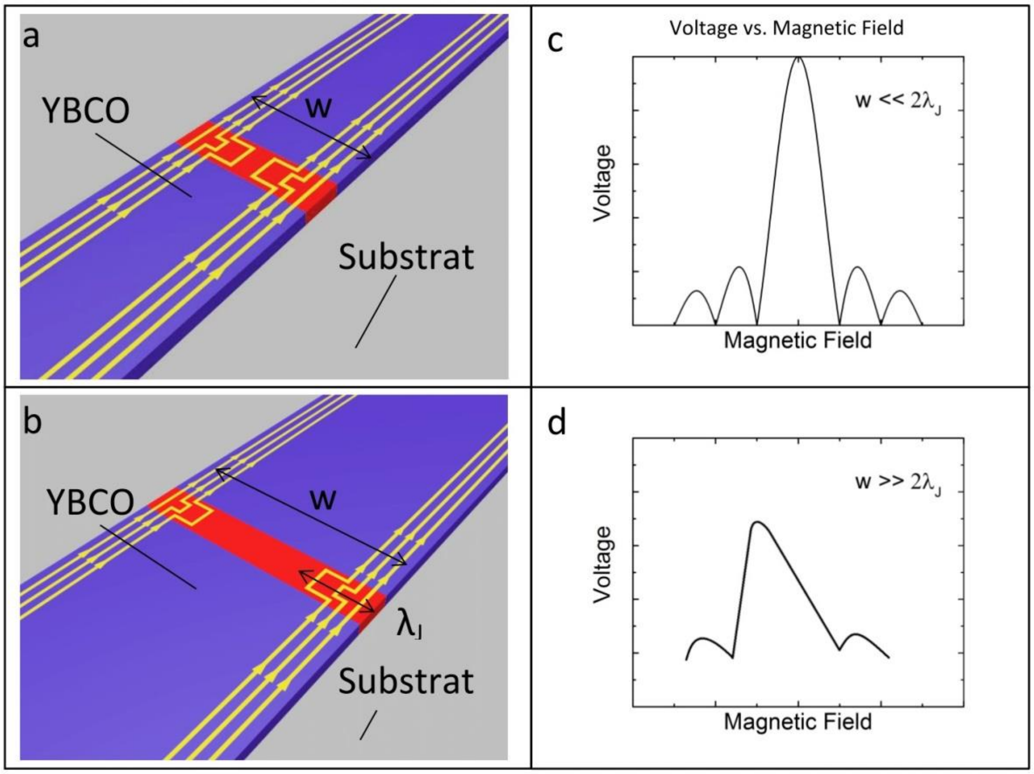

Figure 1. Schematic of Josephson junctions with width smaller (a) and larger (b) then the Josephson penetration depth. The red areas indicate where the ion beam irradiation creates the junction barrier. (c) (d) The voltage as a function of external magnetic field for the different size of junctions.