ED3-1-INV

Digital Applications with High-T_c Superconductors

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One of the early predictions for high-T_c superconductors was their application in digital systems. Not only would the power consumption for cooling be down by a factor of 100, but also the achievable clock rates would be much higher. At that time, the prospects for high-current applications were quite pessimistic. Nowadays, the situation is reversed: the prospects for high-current applications are excellent, especially for magnets, and the prospects for high-T_c digital applications are dim. There reasons are partially technology related, but also related to the needs of the society - complex material issues require big investments and such investments are easier to defend for a room temperature technology than for a cryogenic one: until the need arises that can only be solved by a cryogenic technology. But there is no need to wait, quite a number of applications have successfully been demonstrated in the past. And there are still quite a number of applications around that can be solved with the current technology or with technologies which will mature soon: grain-boundary junctions either on bi-crystals or on step-edges allow the preparation of circuits with a small number of junctions and direct writing of Josephson junctions may yield a tool to create an even larger number of Josephson junctions for digital applications. Since currently only thin film covered substrates with one or two layers of high-T_c superconductors are commercially available, the selection of the right family of Josephson digital circuits is in this context essential.

Keywords: Superconductivity, Digital Devices, High-T_c, Josephson Junctions

ED3-2-INV

Topological superconductivity – new materials for novel devices

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The interplay of induced superconductivity and Dirac physics at the interface of an s-wave superconductor (S) and a 3D topological insulator (TI) turns the surface of the TI into a 2D topological superconductor. Different to conventional superconductors, topological superconductors host exotic subgap states – so-called Majorana modes – at zero energy. In order to employ Majorana modes in future fault-tolerant topological quantum computers, high quality S–TI hybrid devices are required. For achieving pristine interface quality we exploit stencil lithography for full *in situ* fabrication of S–TI hybrid devices via molecular-beam epitaxy. As-prepared Josephson junctions show highly transparent S-TI interfaces and Shapiro response measurements indicate the presence of gapless Andreev bound states, so-called Majorana bound states. To move from single junctions towards complex circuitry for future topological quantum computation architectures, we monolithically integrate two aligned hard masks to the substrate prior to molecular-beam epitaxy. The so-called Jülich process allows to fabricate complex networks of topological insulators and superconductors *in situ* with nm precision.

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Keywords: Topological superconductivity, Majorana, Topological insulator, Molecular-beam epitaxy

ED3-3-INV

Filling and Bridging the THz Gap Using High-T_c Superconducting $Bi_2Sr_2CaCu_2O_{8+\delta}$ Intrinsic Josephson Junction Emitters

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Generation of terahertz (1 THz=10^{12} c/s) electromagnetic waves with a frequency range of 0.3 – 10 THz in-between microwaves and infrared light in the electromagnetic spectrum has been a long-standing issue in the history of optics and optical science and engineering. Recent rapid progress in information technology over the wide frequency spectrum of the electromagnetic waves has urged researchers for the development of TBit technologies. In addition, the demand for the THz waves has also been grown to overcome first the technological barrier to generate THz waves. During last two decades enormous effort has been made. As a result, semiconductor devices such as RTD or QCL devices have been developed successfully. At present, the out-put power of ~1 μW at 1.42 THz by RTD[1] and 0.36 mW at 1.4 THz by cold QCL at 10 K[2] have been reported. Although the THz gap gets narrower and narrower and the valley becomes shallower and shallower, a great difficulty still lies there and hinders many interesting applications in this frequency range.

A new challenge has been started in 2007 after the discovery of continuous and coherent THz emission was discovered in an intrinsic Josephson mesa device fabricated on the single crystal substrate of high temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$, which is well-known as highly 2D anisotropic layered superconductor. Using multi-stacked Josephson layer property, we could manage to develop THz emission up to 2.4 THz[3].

Just recently, we have successfully made a remarkable improvement on high frequency properties by making a new type of devices. We think that this type of devices may be ultimate conceptually and can be applied in the arrays easily. This progress will be reported in my talk together with the recent work on the applications using algae paramylon and the related carbohydrates such as cellulose, curdlan, etc.

References

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ED3-4-INV

Proposal and Fabrication of Hot Electron Bolometer Mixer using a Magnetic Thin Film

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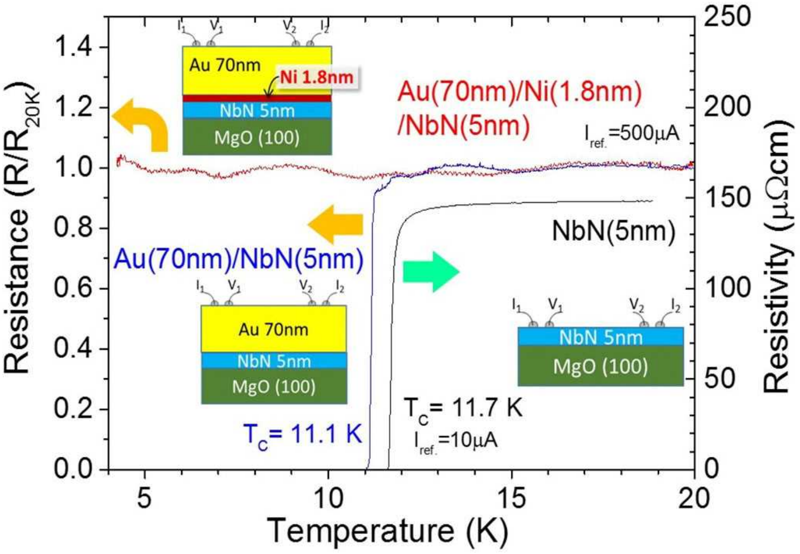
Hot-electron bolometer mixers (HEBMs) are expected to replace SIS mixers as extremely low-noise mixer in applications beyond 1.5 THz. However, the IF bandwidth of an HEBM remains limited to typically 3–5 GHz and it is not sufficient when compared to that of an SIS mixer. Therefore, we proposed a new HEBM structure (Ni-HEBM) using a nickel (Ni) magnetic thin film [1]. Ni-HEBM aims to expand IF bandwidth and improve sensitivity by miniaturizing HEBM which was realized by the controlling the superconducting region with Ni thin film.

HEBM structure comprises with a thin superconducting strip placed between two metal electrodes, and it uses a sudden impedance change in the superconducting transition of the strip. To ensure a good electrical contact, the strip and both electrodes are usually connected via an overlap region on the strip. However, usually superconductivity remained in the region and it has been prevented the miniaturization of conventional HEBM. We found that it is possible to suppress the superconductivity of the niobium nitride (NbN) thin film by the addition of a Ni thin film. Figure shows the temperature dependence of the resistance of the Au (70 nm)/ Ni (1.8 nm)/ NbN (5 nm) trilayer for forming the overlap region of the Ni-HEBM electrodes. For comparison, another bilayer of Au (70 nm)/NbN (5 nm) was prepared (without Ni), which is the structure used for electrodes in a conventional HEBM. The Au/Ni/NbN trilayer film did not show superconductivity until 4.2 K. However, the Au/NbN bilayer film showed superconductivity at 11.1 K.

We fabricated Ni-HEBM with a NbN strip of 0.1 μm-length, and the IF bandwidth was evaluated at 1.9 THz. We confirmed that the IF bandwidth expands, and it was evaluated about 6.9 GHz at 4 K. The uncorrected receiver noise temperature of same Ni-HEBM was also evaluated at 4 K, and it was about 1220 K(DSB) at 2 THz.

Figure. Suppression of the NbN superconductivity under the HEBM metal electrode due to the insertion of the Ni thin film.



Keywords: HEBM, IF bandwidth, Ni, THz