SUPERCONDUCTING TUNNEL JUNCTIONS AND NANOREFRIGERATION USING InAs NANOWIRES

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One of the major interests in modern condensed matter physics is to measure and control heat flow in mesoscopic structures [1]. An already matured method is the use of normal metal-insulator-superconductor (NIS) tunnel junctions, which are capable of cooling down the normal metal by manipulating its electron distribution. An interesting alternative is to replace normal metals with semiconductors, especially with semiconducting nanowires (NW), which have so far been exploited e.g. in Josephson devices [2] and single-electron manipulation [3]without NIS junctions.

Here we demonstrate a method to fabricate high-quality tunnel junctions between superconducting Al reservoirs and epitaxial InAs nanowires. The junctions are formed by evaporating and oxidizing a layer of AlMn on top of degenerately n-doped NWs before evaporating the Al contacts. The junctions exhibit IV characteristics that are in close agreement with the BCS model, and with a voltage bias below the Al gap $\Delta_0 \approx 200\,\mu\mathrm{eV}$ the current is suppressed by over 4 orders of magnitude. In addition, the junctions proved to behave as sensitive thermometers when properly current biased. The method was utilized to fabricate the first prototypes of SI(NW)IS refrigerators, which were able to achieve a peak refrigeration of $\delta T \approx 10\,\mathrm{mK}$ at a bath temperature $T_{bath} \approx 250 - 350\,\mathrm{mK}$. In the prototype devices, both ends of the NW were covered with a large contact with a small tunnel resistance to provide maximum cooling power, whereas the electronic temperature of the NW was probed with smaller junctions placed in the middle of the NW. Even if the refrigeration remained modest in our experiments, the prototype coolers should be fairly easily improved, and due to the minimal volume of the NWs it should be possible to reduce the electronic temperature over one order of magnitude more. Considering further applications, this method provides a versatile and promising tool to research thermoelectric effects in semiconductor nanostructures and nanoscale refrigeration.

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