Superconducting Nanowire Bolometers

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Abstract

We have developed a superconducting nanowire bolometer. This device has also been shown to detect optical radiation and is expected to be very sensitive across a five-decade range of frequencies. We believe that the device can be operated in a photon counting mode. The measured thermal conductance is $\sim 10^{-11}$ W/K. Electrical responsivity is 4.74×10^{10} V/W, and the calculated thermal time constant is ~1 ns for direct detection. The measured noise of this device is 5.87×10^{-19} W/sqrt(Hz)..

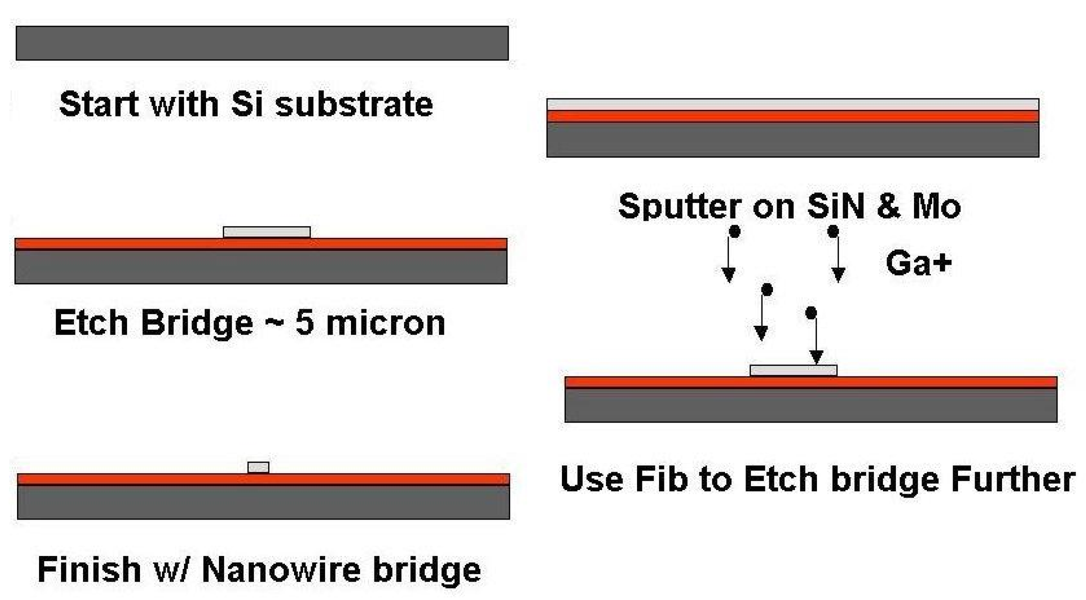
Fabrication

Our fabrication process requires only 3 steps:

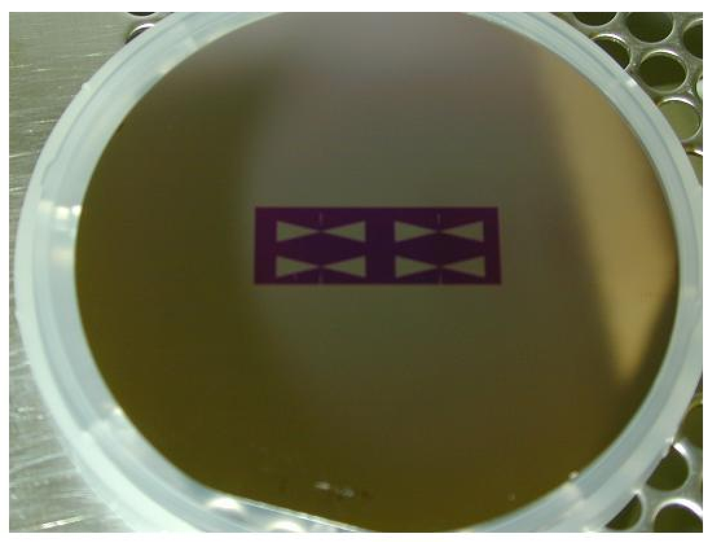
1) Sputtering of SiN (500 nm) and Mo (20 nm) films

2) Photolithography to form bowtie structure with micron sized apex

3) Focused Ion Beam to form nanowires (~ 35 nm) at apex

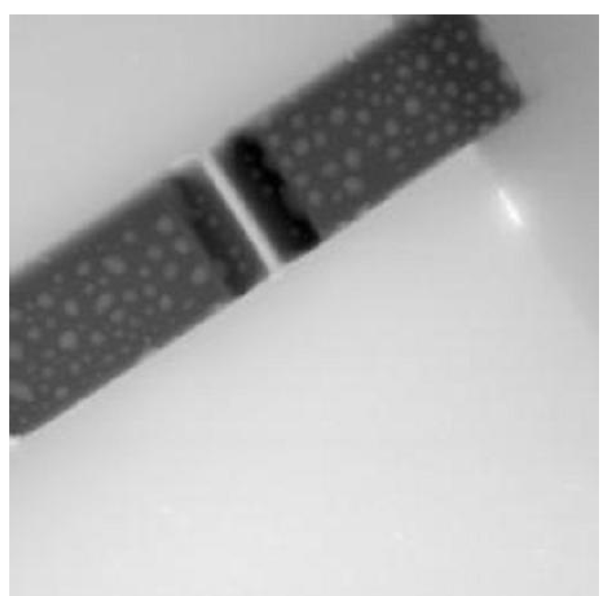


Bowtie Structure:



AFM Image of Nanowire

Size of nanowires: $20 \times 35 \times 500$nm

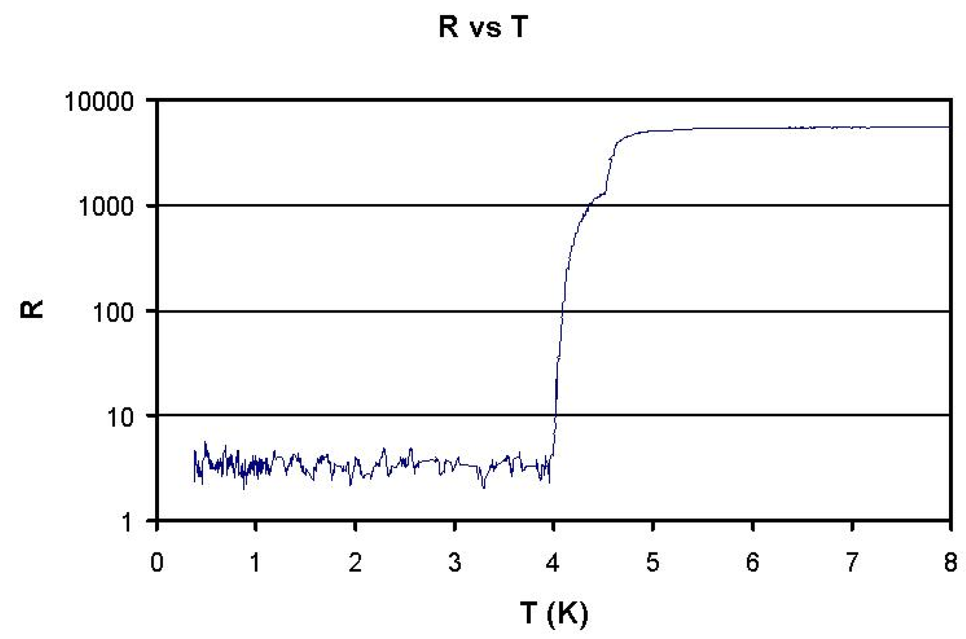


R of T curve

There are two superconductive transition temperatures:

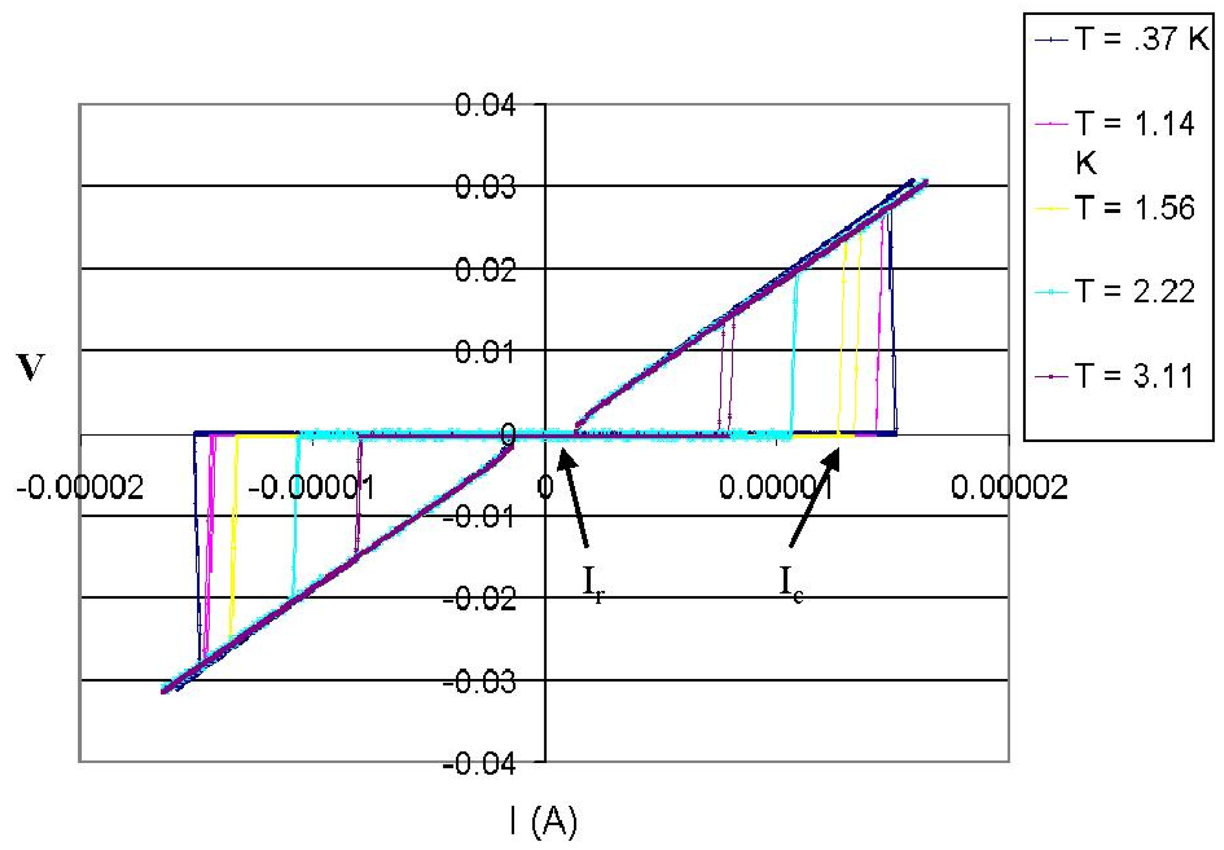
•The bulk transition occurs first, at high temperature

•The second is at a lower temperature for the nanowire device due to reduced dimension superconductivity



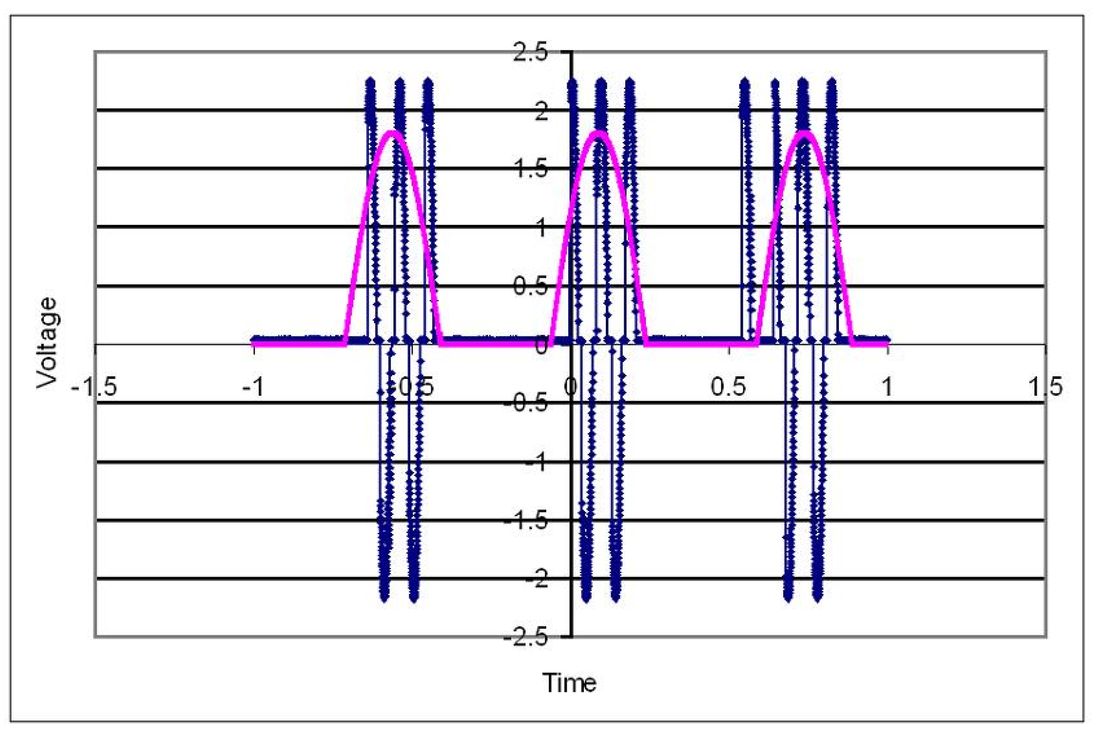
V of I curve

Notice that the critical current I_c is much higher than the retrapping current I_r during the current sweep.



Electromagnetic Radiation Detection

•Light detected at 650 nm, 850 nm, and 1300 nm
•Nanowire has voltage across it only when light is applied



Nanowire voltage (AC current biased) shown in blue, incident electromagnetic radiation intensity in pink.

References:

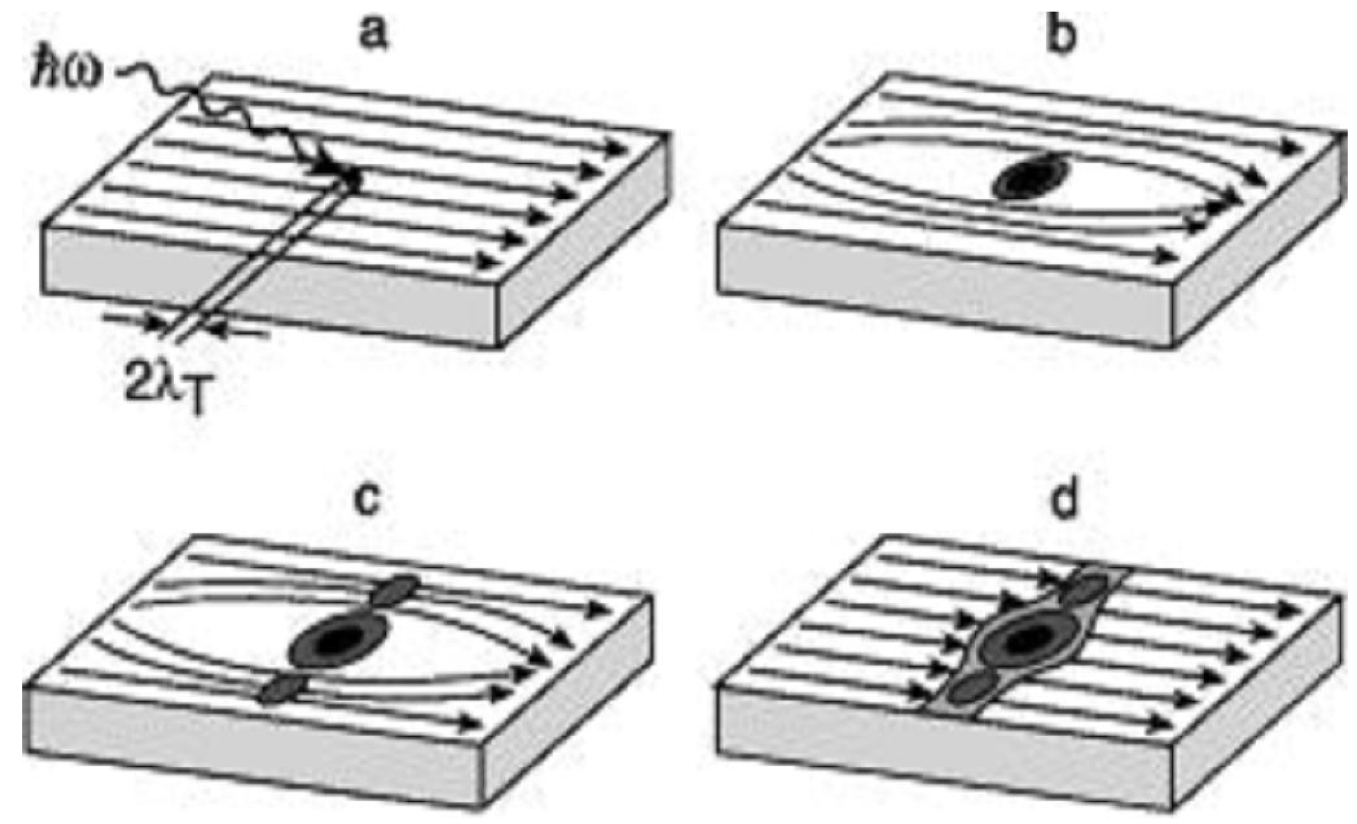
1. G. N. Gol'tsman et al., Appl. Phys. Lett., **79,** 705 (2001)

Photon Counting

•Possible use as a photon counter by current biasing just below critical current

•Gol'tsman has measured the NEP for a photon counter much larger than ours to be 1×10^{-20} W/(Hz)$^{0.5}$ with speeds on the order of ps, and a long wavelength limit around 5 microns

•Our nanowire has a possible long wavelength limit of ~ 1 mm due to its size



Images from [1]. Process for photon counting operation:

a) Absorption of photon.

b) Small region goes normal, increasing current density in side lobes.

c) Side lobes reach critical current density and begin to go normal.

d) Entire nanowire goes normal, increasing impedance, which in turn reduces current allowing the device to reset to the superconducting state.

Direct Detection Testing

Direct detection testing has been performed with AC/DC measurements at 0.4 K. The following parameters have been measured for a nanowire bolometer:

Electrical Responsivity: $S_E = 4.74 \times 10^{10}$ V/W

NEP = 5.87×10^{-19} W/(Hz)$^{1/2}$

Thermal conductance calculated from IV curve: G ~ 1×10^{-11} W/K, implying $\tau = C / G \sim 1$ ns due to small heat capacity

Measured Noise Spectrum