An InAs nanowire-based Josephson junction operated as a self-actuated nanoelectromechanical resonator

Andrey V. Kretinin,[1,2] **Anindya Das**,[2] **Hadas Shtrikman**[2]

[1]School of Physics and Astronomy, University of Manchester, Manchester, UK

[2]Braun Center for Submicron Research, Condensed Matter Physics Department,
Weizmann Institute of Science, Rehovot, Israel
e-mail: andrey.kretinin@manchester.ac.uk

We report an experimental study of a suspended InAs nanowire-based Josephson junction at millikelvin temperatures. In our nanowire-based Josephson junction the normal weak link is formed by the InAs nanowire suspended in vacuum and clamped by two aluminium/titanium ohmic contacts. The previously developed fabrication technique [1] allowed us to form highly transparent superconducting contacts to a normal channel, controlled by an electrostatic gate. At low temperature (T = 15 mK) we observed a gate-controlled supercurrent and peaks in the differential resistance at sub-gap voltages applied across the junction, associated with Multiple Andreev Reflections (MAR) [2,3]. However, closer look on some of the peaks in the differential resistance revealed that their position is independent of the value of the superconducting gap, thus their origin is different from MAR. It is known that a similar behaviour is expected for a Josephson junction coupled to an electromagnetic resonator [4]. In this case the junction's I-V characteristic is modified by the presence of the resonator, provided the a.c.-Josephson oscillations are in resonance with the resonator modes. The bias across the junction V_n, at which the features appear, is defined by the resonant frequency ω_n of the external resonator, $\hbar\omega_n = 2eV_n$. Analysis of the experimental peaks in the differential resistance showed the expected resonant frequency to be at about 10 GHz and 20 GHz, which is in a very good agreement with the eigenfrequencies of the first and second longitudinal vibrational modes of an InAs nanowire of the given length (230 nm). Using a simple model [4] we explain our observation as resonant coupling of the a.c.-Josephson oscillations to the longitudinal vibrations of the nanowire by means of the piezoelectric effect. In our understanding the InAs nanowire operates simultaneously as an a.c.-Josephson junction and a bulk acoustic wave resonator [5]. This sort of Josephson junction devices can be potentially used not only to study nanoelectromechanical systems dynamics, but also as nanometer-scale sources of coherent microwave radiation [5].

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