# Piezoresistive cantilevers based on Si nanowire array strain gauges

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Silicon nanowires obtained via catalytic synthesis offer many extraordinary properties for applications in nanomechanical devices. In particular, their double-clamped horizontally self-assembled growth [1], together with their recently reported giant piezoresistance [2,3], enable an unprecedented approach to obtain highly sensitive piezoresistive nanomechanical cantilever sensors. The use of integrated piezoresistive sensors for detecting cantilever deflections implies important advantages with respect to conventional external optical detection, such as enabling applications where difficulties in laser alignment make optical detection inconvenient, or when sensitivity optimization via size reduction implies scaling dimensions far below the wavelength of the illumination used. Unfortunately, typical detection limits obtained with conventional Si thin film piezoresistive strain gauges are still below the values provided by optical detection. The integration of Si nanowire arrays as piezoresistive strain gauges in cantilevers will allow taking advantage of their giant piezoresistive coefficients, providing and improvement in sensitivity that could reach more than two orders of magnitude and become comparable to that of optical methods.

In this contribution, we present our conclusions concerning the design, fabrication technology and preliminary performance tests of piezoresistive cantilevers based on Si nanowire array strain gauges. Our design is based on the standard double-leg strain gauge cantilever. Finite elements simulations show that the nanowire array must be located only in one side of the neutral axis at the base of the cantilever, so that only tensile or compressive stresses occur in the nanowires when the cantilever is deflected. Fabrication of such structure can be achieved by lithography-guided growth of Si nanowires via the VLS mechanism [4]. Guided growth is possible by using a selective area Au catalyst deposition method that ensures nanoparticle deposition only at silicon exposed areas but not on oxide covered surfaces. The diameter, density and doping concentration of the nanowire arrays are all controlled by tuning the synthesis conditions.

The analysis of the device performance reveals that besides the high sensitivity provided by the large piezoresistive gauge factor of the nanowires, which increases with decreasing NW diameter, signal-to-noise ratio plays a dominant role on determining the deflection detection limit. We find that Hooge noise (1/f) is the dominant noise source, which is essentially due to the reduced volume of the nanowire array resistor and thus the low number of carriers. In consequence, a large number of small diameter nanowires minimizes the total noise while optimizes the piezoresistive sensitivity, resulting in a minimum detectable deflection that can reach the sub-picometer range, a factor 3 to 5 lower than previously reported state-of-the-art piezoresistive Si cantilevers.

[1] A. San Paulo, et al. Appl. Phys. Lett. 87 ( 2005) 053111
[2] R. He, et al. Nat. Nanotech.1(2006) 46
[3] A.C.H. Rowe, Nat. Nanotech. 3(2008) 312
[4] A. San Paulo, et al. Nano Lett. 7 (2007) 1100

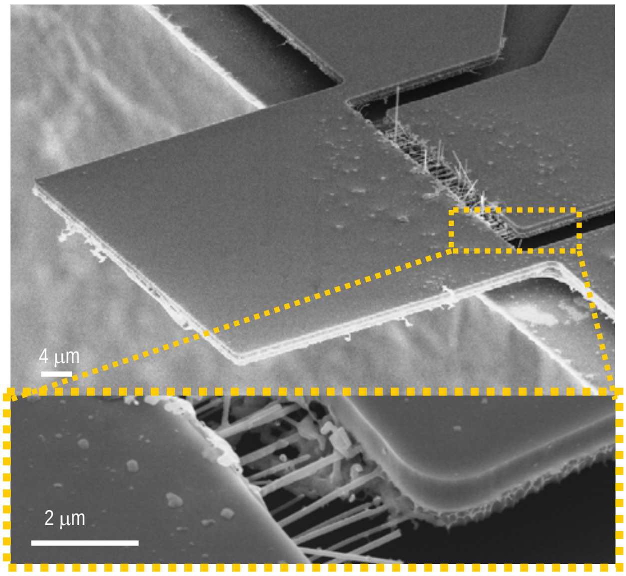


Fig 1. SEM image of the Cantilever

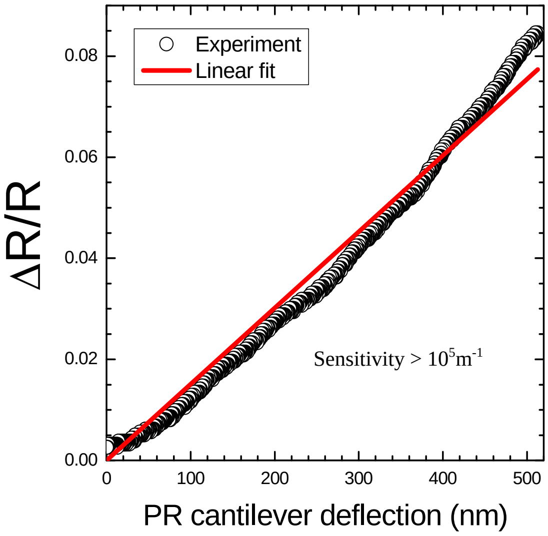


Fig 2. Relative change of resistance vs cantilver deflection.