Si nanowires for ultra-high performance nanoelectromechanical systems

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The catalytic growth of semiconductor nanowires offers the possibility of achieving otherwise unfeasible structural conformations and material combinations at the nanoscale that result in unique physical properties [1]. In consequence, nanowire devices based upon such bottom-up nanofabrication approach, in which functional quasi-1D nanostructures are assembled from chemically synthesized building blocks, have the potential to go beyond not only the size reduction limits, but also the device functionality constraints of top-down lithography based technologies. This is particularly significant for nanoelectromechanical systems (NEMS) because their basic properties are greatly influenced by scaling-laws, thus resulting in completely extreme or different behaviour at the nanoscale.

Among the wide variety of semiconductor materials and growth methods explored so far for bottom-up nanowire device research, Silicon nanowires obtained via the so called vapour-liquid-solid (VLS) mechanism remain as a central issue due to both their unique properties and their dominant relevancy in the electronics industry. In particular, VLS Si nanowires offer exceptional perspectives for applications in NEMS. Their structural quality (low defect density, low surface roughness) and unique electromechanical properties (high stiffness and resonance frequencies, giant piezoresistance) together with recent advances in growth control, promise to allow unprecedented performance of wide variety of systems, ranging from ultra sensitive force or mass sensors to low power, multifunctional RF signal processing components.

In this presentation we will describe several results concerning the fabrication, characterization and performance optimization of several Si NW based NEMS. By combination with top-down micro/nano fabrication methods, the VLS synthesis can be used to produce horizontally suspended nanowires between the sidewalls of prefabricated Si microstructures [2]. This approach can be applied to obtain single nanowire or nanowire array based beam-like structures [3], which serve as basic building blocks for nanomechanical devices. The characterization of the elasticity [4], mechanical resonances [5] and piezoresistance [6] of such structures [fig.1 (a) and (b)] has lead us to propose the development of nanomechanical resonators and piezoresistive transducers as devices that would directly benefit from the extraordinary properties of Si nanowires. It will be discussed how nanomechanical resonators based on individual, extremely small nanowires can provide a detection limit for inertial mass sensing close to that required for atom resolution mass spectrometry [fig.1 (c)], whereas piezoresistive strain gauges based on highly dense nanowire arrays can be applied to obtain cantilevers [fig.1 (d)] with a detection limit for displacement sensing up to ten times better than that provided by conventional Si thin film piezoresistive cantilevers.

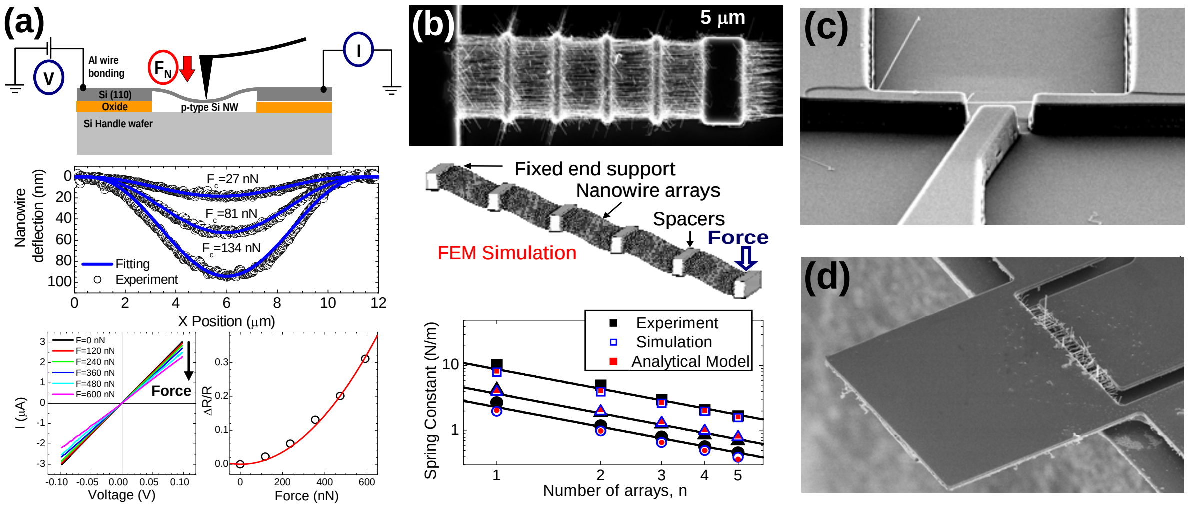

Figure 1. *Mechanical elasticity and piezoresistance measurements on horizontally grown Si nanowires (a); Spring constant measurements and finite element simulations of cantilever-like structures composed of several horizontal nanowire arrays (b); Single nanowire nanomechanical resonator (c) and piezoresisitive cantilever sensor based on a Si nanowire array strain gauge (d).*

References

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