PUBLISHABLE SUMMARY

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PING – Piezoelectric nanogenerators on suspended microstructures for energy harvesting

Since existing micro-devices may only require minuscule amounts of power, the ability to convert free energy harvested from the environment into electric energy has very high potential, especially for implantable medical devices and wireless sensors networks. However, existing systems for energy harvesting are not sufficiently efficient, cheap, and compact; in particular, the output power of conventional integrable piezoelectric devices is rather low. In 2006 Prof. Zhong Lin Wang (Georgia Institute of Technology) has proposed to use arrays of piezoelectric nanowires for transducing mechanical energy into electrical energy; this strategy may result in outstanding advantages as piezoelectric nanostructures have larger deformations for a given input force, higher piezoelectric coefficients, and much larger fracture strains. Nevertheless, existing nanogenerators are largely sub-optimal. For these reasons, the goal of this project was, first, to develop a modified (low-temperature) aqueous chemical growth process suitable for improving the nanowires homogeneity as well as for increasing the nanowires length and, second, to co-integrate sufficiently long ZnO nanowires with suspended microstructures (diaphragms and bridges), thus allowing a more efficient transduction of incoming acoustic energy into deflections of nanowires.

The project has been terminated after 6 months because the researcher, Dr. Jyoti Prakash Kar, has been appointed as an Assistant Professor by the National Institute of Technology – NIT (Rourkela, India). Despite such very short duration, the project has fully achieved its objectives and technical goals for the period and some tasks have even been anticipated.

Several configurations of micro-heaters and suspended membranes have been designed and characterized by FEM computations. For instance, figure 1 shows the membrane area (top view) of a multi-ring micro-heater (a), an enlarged view of the heater region (b), the temperature distribution in a conventional micro-heater (c) and in an improved micro-heater with superior temperature uniformity and without hot-spots (d).

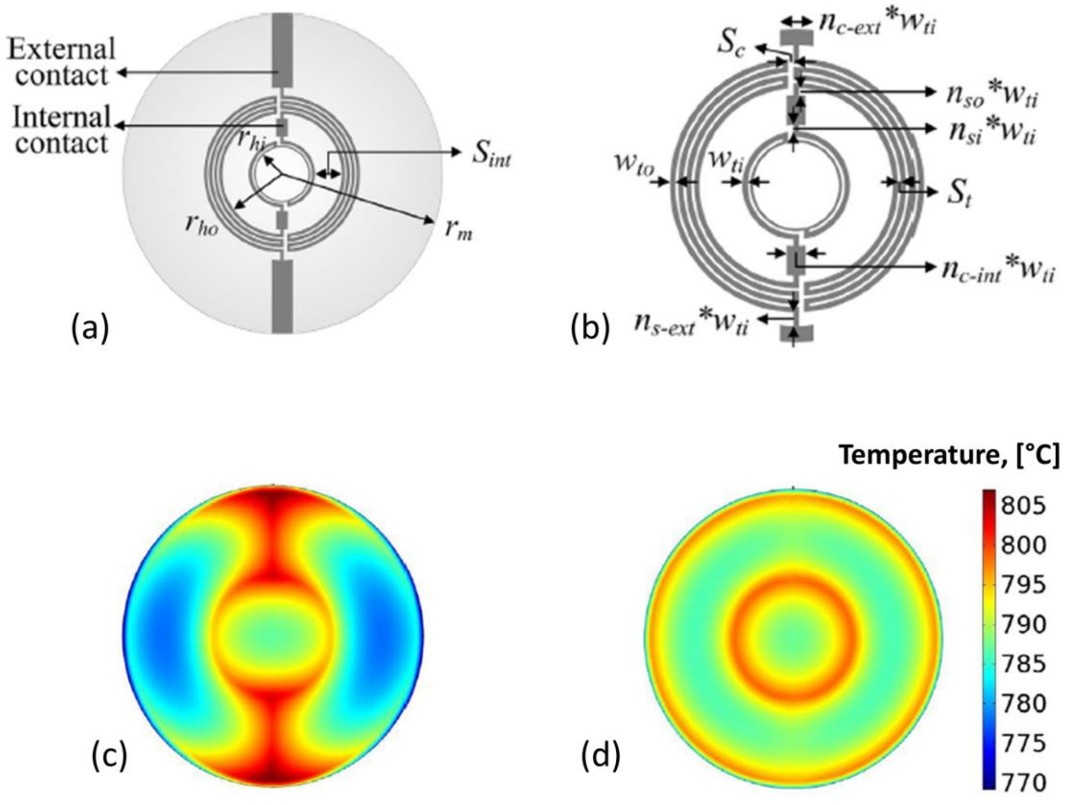

Figure 1. Membrane area (top view) of a multi-ring micro-heater (a) and enlarged view of the heater region (b). Temperature distribution in a conventional micro-heater (c) and in an improved micro-heater (d).

Besides, an innovative method for the wet-chemistry synthesis of ZnO nanowires has been developed; in practice, instead of heating all the nutrient solution, only the substrate is heated, resulting in longer nanowires and substantially reducing both waste-chemicals and power consumption. The morphological and crystalline quality of the nanowires have been evaluated by scanning electron microscopy (SEM), X-ray diffraction (XRD), and photo-luminescence; in particular, figure 2 shows an array of ultra-long and separable ZnO nanowires (a), an array of high-density and compact ZnO nanorods (b), and a ZnO nanoparticle (c).

Despite the early termination, the project allowed to obtain significant scientific and technological results; in particular the wet-chemistry synthesis of ZnO nanowires by means of local substrate heating seems very promising for fabricating high performance devices for both energy harvesting and piezotronics. Moreover, in view of the outstanding potential of ZnO nanowires, the development of a low temperature, low cost, and large area method for growing ZnO nanowires in a much more environmentally friendly (low power and reduced waste of chemicals) may also reveal an important achievement. The substrate-heating approach is currently being further developed at the University of Tor Vergata by other researchers (at the time of this writing the first packaged devices are being electrically characterized; after the electrical characterization a manuscript will be submitted to an international peer-reviewed journal). The project was also instrumental to promoting cooperation and scientific relations between Indian and European researchers; the excellent human and scientific relations built by Dr. Kar with many young and experienced researchers at the University of Tor Vergata are also an important outcome.

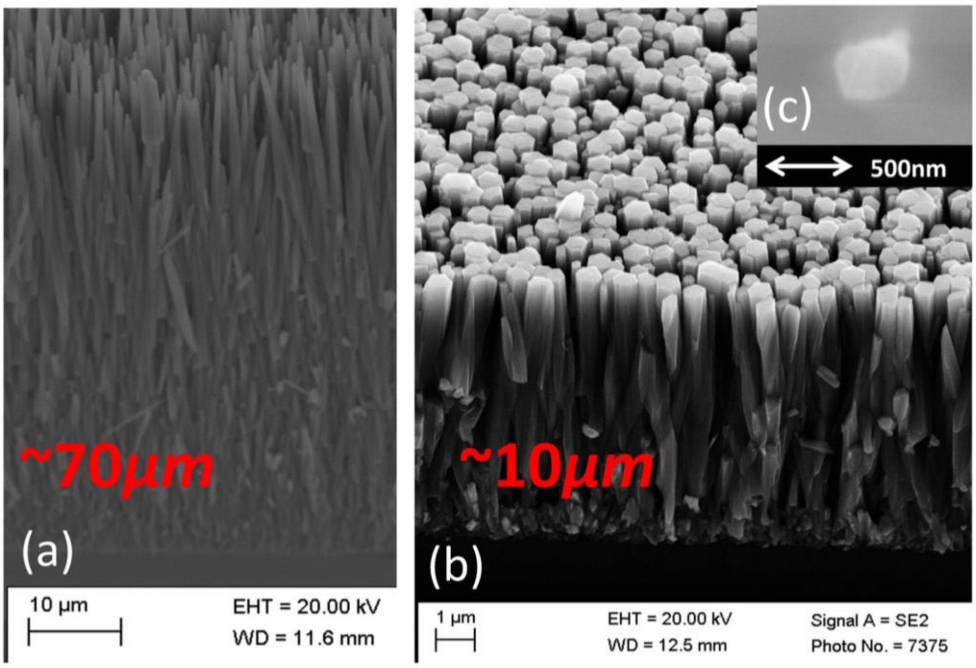

Figure 2. ZnO nanostructures grown by innovative wet-chemistry processes. Ultra-long separable nanowires (a); long, high-density, and compact nanorods (b); nanoparticle (c).

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