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ESI Special Topics, March 2005
Citing URL: http://www.esi-topics.com/fmf/2005/march05-ZhongLinWang.html

From •>>March 2005

Zhong Lin Wang answers a few questions about this month's fast moving front in the field of Multidisciplinary.

Field: Multidisciplinary
Article: Spontaneous polarization-induced nanohelixes, nanosprings, and nanorings of piezoelectric nanobelts
Authors: Kong, XY;**Wang, ZL**
Journal: NANO LETT,3: (12) 1625-1631, DEC 2003
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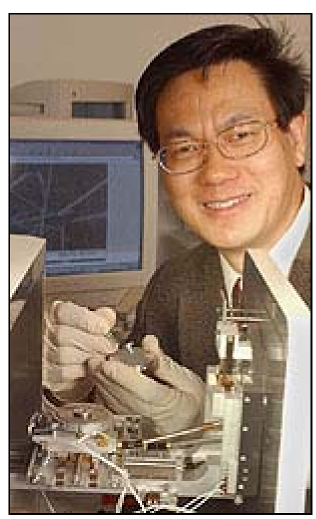
Related Information...

March 1, 2005: This paper has also been named the New Hot Paper in Chemistry for March 2005.

ST: Why do you think your paper is highly cited?



In parallel to semiconductor nanostructures, piezoelectric- and ferroelectric-based smart materials are equally important, because they are the transducers and actuators for nano-scale machines and devices. But there had been no report about the success of synthesizing piezoelectric one-dimensional nanostructures. In this paper, we report, for the very first time, the success of synthesizing structurally controlled piezoelectric and ferroelectric ZnO nanobelts of sizes 10-60 nm in width and 5-20 nm in thickness. The most exciting result is the formation of single crystalline ZnO helical nanosprings due to spontaneous polarization. Our manuscript is the first paper that analyzes such structures that will have major scientific and technological impacts on the field.

ST: Does it describe a new discovery or new methodology that's useful to others?

Major results:

1. Nanobelts, exhibiting piezoelectric effect and

spontaneous polarization, are synthesized for the very first time. The wurtzite-structured nanobelt grows along the a-axis, with its top and bottom surfaces the polar (0001) c-plane. Owing to the positive and negative ionic charges on the zinc- and oxygen-terminated basal planes, respectively, a spontaneous polarization normal to the nanobelt surface is induced. This will lead to a whole new field in nanowire/nanobelt research.

> ***"In this paper, we report, for the very first time, the success of synthesizing structurally controlled piezoelectric and ferroelectric ZnO nanobelts of sizes 10-60 nm in width and 5-20 nm in thickness."***

2. Helical nanosprings/nanocoils, formed by rolling up single crystalline nanobelts, are reported for the very first time. The mechanism for the helical growth is suggested to be a consequence of minimizing the total energy contributed by spontaneous polarization and elasticity. Our theoretical model gives an excellent explanation to the experimental observation. This is a new mechanism for forming the helical nanostructures. The helical structure will have a wide range of impacts both in scientific research and technological applications.
3. The growth of polar-facets-dominated nanobelt surfaces is a major step towards the development of piezoelectric and possibly, ferroelectric, one-dimensional nanostructures. Since the ZnO (2 0) plane has a lower surface energy, lower than that of either (0001) or (01 0), a fast growth of nanobelt structure that is dominated by the (0001) polar surface is energetically unfavorable. But the success of the controlled growth of (0001) plane-dominated nanobelts shows that controlling growth kinetics and experimental conditions can overcome the barrier placed by surface energy in nanostructure growth, thus, opening a new channel for the growth of structurally controlled nanobelts of technological importance.

ST: How did you become involved in this research?

Nanowire and nanotube-based materials have been demonstrated as building blocks for nanocircuits, nanosystems, and nano-optoelectronics. Synthesis, characterization, and applications of oxide nanostructures are the major research directions of my group. Quasi-one-dimensional nanostructures—so called nanobelts or nanoribbons—have been successfully synthesized for the semiconducting oxides of zinc, tin, indium, cadmium, and gallium, by simply evaporating the desired commercial metal oxide powders at high temperatures in our lab. [1]. The *Science* paper [1] we published in 2001 is the most-cited paper in the field of chemistry from the period 2002-2003. The belt-like morphology appears to be a unique and common structural characteristic for the family of semiconducting oxides with cations of different valence states and materials of distinct crystallographic structures.

Using the technique demonstrated for measuring the mechanical properties of carbon nanotubes based on *in situ* transmission electron microscopy [2,3], the bending modulus of the oxide nanobelts and the work function at the tip have been measured. Field-effect transistors [4] and ultra-sensitive nano-size gas sensors [5], nanoresonators, and nanocantilevers [6], have also been fabricated based on individual nanobelts. Thermal conductivity of a nanobelt has also been measured. Very recently, nanobelts, nanorings, and nanosprings that exhibit piezoelectric properties have been synthesized, which are potential candidates for nano-scale traducers, actuators, and sensors [7, 8, 9, 10]. This presentation will focus on our recent progress in the controlled growth, nano-scale property measurements and nano-size device fabrication using oxide nanostructures that are semiconducting and piezoelectric.

ST: Could you summarize the significance of your paper in layman's terms?

Its scientific impacts:

1. Helical chain structure is the most fundamental structural configuration for DNA and many biological proteins. For one-dimensional nanostructures, nanosprings and nanorings have been observed for carbon nanotubes. The carbon nanosprings are created due to a periodic arrangement of the paired pentagon and heptagon carbon rings in the hexagonal carbon network, and they are the point-defect-induced structures. The striking feature of the helical nanosprings for single crystalline ZnO nanobelt is that they are the spontaneous polarization-induced structure.
2. Quantitative analysis about the elastic energy involved in the formation of helical structure could provide an experimental measurement on the electrostatic energy induced by polarization, leading to a possible technique for measuring the dipole moment and surface-charge-distribution in nanobelt structures.
3. The nanobelts and nanosprings are an ideal system for understanding piezoelectricity-

and polarization-induced ferroelectricity at nano-scale.
4. This research opens a field in the application of wurtzite-structured nanobelt materials, such as GaN, AlN, ZnO, and ZnS, in transducers and sensors, using the polarization-driven devices.

Technological impacts:

1. The different polar surfaces could be used as selective catalysts.
2. The piezoelectric and ferroelectric nanobelt structures may open up many possible research applications at nano-scale, such as nanoinductors, nanospring-based transducers and actuators, and tunable functional components for micro- and nano-electromechanical systems (MEMS/NEMS).
3. The tunable pitch distance in the helical nanosprings could be used for separating DNA double helix chains and tailoring DNA structures via electromechanical coupling.

ST: How did you become involved in this research?

Zhong Lin Wang received his Ph.D. in Physics from Arizona State University in 1987. He is currently a Regents' Professor, and the Director of the Center for Nanoscience and Nanotechnology at the Georgia Institute of Technology. He is among the world's 25 most-cited authors in the field of nanotechnology for the last decade (Thomson-ISI®). His publications have been cited a total of over 7,000 times. He has received the 2001 S.T. Li prize for Outstanding Contributions in Nanoscience and Nanotechnology, the 2000 Georgia Tech Faculty Research Award, and the 1999 Burton Medal from the Microscopy Society of America. His most recent research focuses on oxide nanobelts and nanowires, *insitu* techniques for nano-scale measurements, self-assembly nanostructures, fabrication of nano devices for bio-sensing, and properties of magnetic nanostructures. Click for more details.

References:

- [1] Z.W. Pan, Z.R. Dai and Z.L. Wang, *Science*, 209 (2001) 1947.
- [2] P. Poncharal, Z.L. Wang, D. Ugarte and W.A. de Heer, Science, 283 (1999) 1513; *Electron Microscopy of Nanotubes*, ed. Z.L. Wang and C. Hui, Kluwer Academic Publisher (2003).
- [3] R.P. Gao, Z.L. Wang, Z.G. Bai, W. de Heer, L. Dai and M. Gao, *Phys. Rev. Letts.*, 85 (2000) 622; Z.L. Wang, P. Poncharal and W.A. De Heer, *Pure Appl. Chem*. Vol. 72 (2000) 209.
- [4] M. Arnold, P. Avouris, Z.L. Wang,. *Phys. Chem*. B, 107 (2002) 659.
- [5] E. Comini, G. Faglia, G. Sberveglieri, Zhengwei Pan, Z. L. Wang, *Applied Physics Letters*, 81 (2002) 1869.
- [6] W. Hughes and Z.L. Wang, *Appl. Phys. Letts*., 82 (2003) 2886.
- [7] X.Y. Kong and Z.L. Wang, *Nano Letters*, 2 (2003) 1625 + cover.
- [8] Z.L. Wang, X.Y. Kong and J.M. Zuo, *Phys. Rev. Letts.* 91 (2003) 185502.
- [9] "Nanowires and Nanobelts – materials, properties and devices; Vol. I: Metal and Semiconductor Nanowires", Vol. II: Nanowires and Nanobelts of Functional Materials" edited by Z.L. Wang, Kluwer Academic Publisher (2003).
- [10] X.Y. Kong, Y. Ding, R.S. Yang, Z.L. Wang "Single-crystal nanorings formed by epitaxial self-coiling of polar-nanobelts," *Science*, 303 (2004) 1348.

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