GaN Nanowires Are The Giants Of Piezoelectricity

Jan 27, 2011

The piezoelectric coefficient in 2.4 nm diameter GaN nanowires is about 100 times larger when compared to the coefficient of the material on a macroscale.

GaN and ZnO are two of the most technologically relevant semiconducting materials in optoelectronics today. GaN is ubiquitous in blue lasers and LEDs whilst ZnO is used in optoelectronics and sensors.

Both materials are also used in more complex devices such as resonators and, more recently, in nanogenerators that convert mechanical energy from the environment (body movements, for example) to power electronic devices.

The latter application relies on the fact that GaN and ZnO are also piezoelectric materials, meaning that they produce electric charges as they are deformed.

In the past few years, nanostructures made of these materials have shown a plethora of potential functionalities, ranging from single-nanowire lasers and LEDs.

In a recent publication, Horacio Espinosa and Ravi Agrawal of Northwestern University based in Illinois, have reported that piezoelectricity in GaN and ZnO nanowires is in fact enhanced by as much as two orders of magnitude as the diameter of the nanowires is decreased.

"This finding is very exciting because it suggests that constructing nanogenerators, sensors and other devices from smaller nanowires will greatly improve their output and sensitivity," Espinosa said.

"We used a computational method called Density Functional Theory (DFT) to model GaN and ZnO nanowires of diameters ranging from 0.6 nm to 2.4 nm," added Agrawal. The computational method is able to predict the electronic distribution of the nanowires as they are deformed and thus allows calculation of their piezoelectric coefficients.

The researchers’ results show that the piezoelectric coefficient in 2.4 nm diameter nanowires is about 20 times larger and about 100 times larger for ZnO and GaN nanowires, respectively, when compared to the coefficient of the materials at the macroscale. This confirms previous computational findings on ZnO nanostructures that showed a similar increase in piezoelectric properties.

However, the researchers say that calculations for piezoelectricity of GaN nanowires as a function of size were carried out in this work for the first time, and the results are clearly more promising as GaN shows a more prominent increase.

"Our calculations reveal that the increase in piezoelectricity is a result of the redistribution of electrons in the nanowire surface, which leads to an increase in the strain-dependent polarisation with respect to the bulk materials," Espinosa said.

The findings may have important implications in the field of energy harvesting as well as for fundamental science.

For energy harvesting, where piezoelectric elements are used to convert mechanical energy to electrical energy to power electronic devices, these results point to a reduction in size of the piezoelectric elements down to the nanometre scale. Energy harvesting devices built from small-diameter nanowires should in principle be able to produce more electrical energy from the same amount of mechanical energy than their bulk counterparts.

In terms of fundamental science, these results support previous conclusions that are important on the nanoscale. The scientists say that by tailoring the size of nanostructures, their mechanical, electrical and thermal properties can be tuned as well.
GaN Nanowires are the Giants of Piezoe...

“Our focus remains on understanding the fundamental principles governing the behaviour of nanostructures as a function of their size,” say the researchers. “One of the most important issues that needs to be addressed is to obtain experimental confirmation of these results, and establish up to what size the giant piezoelectric effects remain significant.”

Espinosa and Agrawal hope their work will spur new interest in the electromechanical properties of nanostructures, both from theoretical and experimental standpoints, in order to clear the path for the design and optimisation of future nanoscale devices.

If you want to find out more about this research, see the paper, “Giant Piezoelectric Size Effects in Zinc Oxide and Gallium Nitride Nanowires: A First Principles Investigation” by Ravi Agrawal and Horacio D. Espinosa published online in Nano Letters on January 11, 2011 (DOI: 10.1021/nl104004d).

NEWS

Compound Semiconductor. The most respected, authoritative and widely read information source connecting the community since 1995. To view the latest issue of Compound Semiconductor, click here.

To register free of charge to receive news via e-mail on a weekly basis click here.

Search the Compound Semiconductor web site

Submit your Lab & Fab article

It is imperative that CompoundSemiconductor.net remains a timely resource for this industry, so we are only interested in highlighting very recent work reported in academic papers. Therefore, please only consider writing a short piece highlighting your work if you have a journal paper that has been accepted and about to appear in press, or a paper that has been published within the last month. For further guidelines, click here.

SHARE THIS

Email this article to a friend

Comnnotes Cite-U-Like Del.icio.us Digg Facebook

Google Live Spaces MySpace NewsVine Reddit

Stumbleupon Technorati Twitter Yahoo! My Web