Piezotronics and piezo-phototronics with third-generation semiconductors

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Video Abstract

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Abstract

New technologies for enhancing electronics and photonics are crucial for emerging applications in energy, sensing, artificial intelligence, and countless other areas. But these technologies are hard to come by using traditional semiconductors. Over the past decade, so-called third-generation semiconductors have proved to be a boon to materials science and engineering, giving researchers increased versatility in boosting device performance. Among the most promising properties of these materials is piezoelectricity—the ability to convert mechanical energy to electrical energy and vice versa. The December 2018 issue of the MRS Bulletin takes a look at how researchers are exploiting piezoelectricity in semiconductors to enhance electronic and photonic devices like never before, providing a glimpse into the world of piezotronics and piezo-phototronics. In 2006, Zhong Lin Wang's group at Georgia Tech discovered that piezoelectricity in zinc oxide nanowires exerts a gating effect like that in transistors. Since then, researchers have sought to incorporate mechanical sensitivity into traditional electronics, providing a new lever of sorts with which to modulate device performance. Today, that piezotronic effect is helping researchers create increasingly responsive biochemical, gas, and humidity sensors for instance. For gated optoelectronic devices such as LEDs, photo-sensors, and solar cells, the piezo-phototronic effect is proving just as valuable. The coupling of piezoelectricity, semiconductor transport, and light-matter interaction enables researchers to engineer the behavior of photogenerated carriers mechanically. The result is a new class of devices that are uniquely adaptive and intuitive, suitable for applications in sensing and human-machine interfacing. The piezo-phototronic principle is also helping researchers engineer the interfaces between semiconductors and electrolytes to yield more efficient photoanodes and improved photocatalysts for chemical and biochemical reactions. Although one-dimensional materials have been the primary medium for realizing piezotronic and piezo-phototronic effects, two-dimensional material applications are rapidly emerging. Research suggests the feasibility of coupling piezo-effects with the exotic properties native to 2D materials, such as quantum transport and topological properties. Further advancements in piezotronics and piezo-phototronics will require a much better understanding of the underlying physics that governs the operation of such devices. In turn, more sophisticated methods for designing, fabricating, and characterizing materials that support piezo-effects are needed. But with the potential to revolutionize modern energy, sensing, and human-integrated technologies, the future of this emerging area of materials research looks bright. For more information about these and other advances, check out the December 2018 issue of the MRS Bulletin.