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In operando x-ray imaging of nanoscale devices: Composition, valence, and internal electrical fields

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We introduce a method for directly imaging depletion layers in operando with elemental specificity and chemical speciation at sub-100 nm spatial resolution applicable to today's three-dimensional electronic architectures. These typically contain complex, multicomponent designs consisting of epitaxial heterostructures, buried domains, or nanostructures with different shapes and sizes. Although the variety of devices is immense, they commonly rely on carrier separation in a built-in potential induced by composition or strain gradients. To image these, we scanned a focused synchrotron x-ray nanobeam over a single semiconductor nanowire heterostructure and simultaneously measured the current through the device and the emitted characteristic x-rays as a function of the incoming hard x-ray energy. With these results, it is possible to identify the compositional and molecular structure as well as localize the electrical fields present under typical working conditions. This information allows us to draw an energy band diagram consistent with the elemental distribution and a high-resolution chemical speciation map.

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