Tabletop Coherent Extreme Ultraviolet Beams for Nondestructive Metrology of Ultrathin Films and Nanostructured Materials

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Advances in nanofabrication have made it possible to scale the characteristic dimension of engineered systems deep into the nano regime (<10 nm), facilitating the growth of atomically precise thin films and 3D designer materials. However, bulk material models' predictions no longer apply at these length scales, from thermal and elastic properties to electronic transport and beyond. Specifically, traditional metrology techniques struggle to reliably probe the elastic properties of ultrathin films (<<100 nm) where the bulk elasticity models are predicted to break down. The nontrivial behavior of nanosystems and limitations of traditional techniques impede both technological advances, including iterative device design and process control of nanoscale devices, and the fundamental understanding of how material properties change at the nanoscale as a function of size, doping, or other structural changes. In this work, we present several advances in nanoscale metrology using tabletop high harmonic coherent extreme ultraviolet (EUV) beams with wavelengths (<30 nm) and pulse durations (<10 fs) that are well matched to the intrinsic length and time scales of nanostructured devices. Previously, we used coherent EUV beams in a nondestructive photoacoustic technique to characterize the full elastic tensor of isotropic ultrathin films with varying levels of hydrogenation used to lower their dielectric constants. Contrary to past assumptions, we found that the Poisson's ratio of these films does not remain constant as a function of hydrogenation but rather significantly increases below a critical value of network connectivity. Here, we utilize this technique to probe nanoscale deviations from bulk elastic properties in a series of ultrathin films with nominally identical properties but varying thicknesses, down to 11 nm. Additionally, we extend EUV photoacoustic nanometrology capabilities to probe dynamics in complex nanostructured systems, including inverse meta-lattices, ultrathin metallic nanomeshes, and metal matrix composites using illuminated transducers and visible transient grating as excitation modalities.