Chapter 54
Low-Loss Phonon Polaritons in Nanostructured Dielectrics

Alexander J. Giles, S. Dai, Chase T. Ellis, J. C. Owrutsky, J. G. Tischler, O. J. Glembocki, F. J. Bezares, R. Kasica, L. Shirey, M. M. Fogler, Dimitri Basov, and J. D. Caldwell

Abstract Plasmonics provides great promise for nanophotonic applications. However, the high optical losses inherent in metal-based plasmonic systems have limited progress. Thus, it is critical to identify alternative low-loss materials. One alternative is polar dielectrics that support surface phonon polariton (SPhP) modes, where the confinement of infrared light is aided by optical phonons. SiC nanopillar arrays support such modes, exhibiting a dipolar resonance transverse to the nanopillar axis and a monopolar resonance associated with the longitudinal axis dependent upon the SiC substrate. Both exhibit exceptionally narrow linewidths (7–24 cm^{-1}), with quality factors of 40–135, which exceed the theoretical limit of plasmonic systems, with extreme subwavelength confinement of $(\lambda res3/Veff)1/3 = 50–200$. These observations promise to reinvigorate research in SPhP phenomena and their use for nanophotonic applications. Another approach is the use of hyperbolic materials, which have been a focus of the nanophotonics community for their potential to realize sub-diffractional imaging and focusing of light, and novel optical properties, such as a negative index of refraction. The recent observation that hexagonal boron nitride (hBN) is a natural, high efficiency hyperbolic material has led to a surge in research within this field. Due to the low-loss nature, van der Waals bonding and extreme crystal anisotropy, the hyperbolic polaritons within hBN are not only promising for novel applications within the

A.J. Giles (✉) • C.T. Ellis • J.C. Owrutsky • J.G. Tischler • O.J. Glembocki • L. Shirey • J.D. Caldwell
U.S. Naval Research Laboratory, Washington, DC, USA
e-mail: alexander.giles.ctr@nrl.navy.mil

S. Dai • M.M. Fogler • D. Basov
University of California at San Diego, La Jolla, CA, USA

F.J. Bezares
The Institute of Photonic Sciences, Barcelona, Spain

R. Kasica
Center for Nanoscale Technology, National Institutes of Standards and Technology, Gaithersburg, MD, USA

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mid-infrared, but is also extremely well suited for fundamental investigations into their resonant behaviors. We have used scattering near-field optical microscopy (s-SNOM) to directly probe the local surface electromagnetic fields of three-dimensionally confined nanostructures of hBN, reporting the first experimental observation of frequency dependent internal angular reflection within a hyperbolic nanostructure, a phenomenon previously theoretically predicted.

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