O 52: Poster Session IV: Poster to Mini-Symposium: Infrared nano-optics II

Time: Tuesday 13:30–15:30 Location: P

O 52.1 Tue 13:30 P

Local infrared properties of pure antimony in reduced dimension — •Max Dario Siebenkotten[1], Konstantin Wirth[1], Peter Kerres[1], Lisa Schäfer[1], Anne Frommelius[2], Ulrich Simon[2], Matthias Wuttig[1], and Thomas Taubner[1] — [1]Institute of Physics (IA), RWTH Aachen — [2]Institute of Inorganic Chemistry, RWTH Aachen

Much progress has been made in recent years in advancing phase-change materials (PCMs) towards becoming a commercial random access memory (RAM) technology [1]. One major remaining issue is that the precise stoichiometry in the region of interest in PCM memory cells still eludes control, particularly when that region is repeatedly switched between its amorphous and crystalline state [2]. Pure antimony is a PCM and recently it has been shown that switching can be achieved when it is confined in reduced dimensions [2].

In this work the infrared optical properties of antimony thin films and nanoparticles are investigated by scattering type scanning near-field optical microscopy (s-SNOM). s-SNOM allows for the study down to the single nanoparticle level. The antimony nanoparticles show distinguishable infrared optical response, at least statistically, between their amorphous and crystalline phase. Confined antimony is found to show pronounced differences to bulk antimony in the infrared, as has been shown for the optical region on thin films before [3].

[1] Kooi, Wuttig, Adv. Mater. 32, 1908302 (2020)
[2] Salinga et al., Nat. Mater. 17, 681-685 (2018)
[3] Cheng et al., arXiv:2008.09007 (2020)

O 52.2 Tue 13:30 P

Vibrational Coupling to Epsilon-Near-Zero Waveguide Modes — •Thomas G Folland[1], Guanyu Lu[2], Autumn Bruncz[2,3], J. Ryan Nolen[2], Marko Tadjer[4], and Joshua D Caldwell[2] — [1]School of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, USA, 52242 — [2]Department of Mechanical Engineering, Vanderbilt University, Nashville, Tennessee 37212, United States — [3]Department of Physics, University of Alabama in Huntsville, Huntsville, Alabama 35899, United States — [4]U.S. Naval Research Laboratory, Washington, D.C. 20375, United States

Epsilon near zero modes offer extreme field enhancement that can be utilized for developing enhanced sensing schemes. Here we fabricate high aspect ratio gratings (up to 24.8 um height with greater than 5 um pitch) of 4H-SiC, with resonant modes that couple to transverse magnetic and transverse electric incident fields. These correspond to metal insulator metal waveguide modes propagating downward into the substrate. The cavity formed by the finite length of the waveguide allows for strong absorption of incident infrared light (>80%) with Q factors in excess of 90, including an epsilon near zero waveguide mode with epsilon = 0.0574 + 0.008i. The localization of the electromagnetic fields within the gap between the grating teeth suggests an opportunity to realize a new platform for studying vibrational coupling in liquid environments, with potential opportunities for enhanced spectroscopies. We show that these modes are supported in anhydrous and aqueous environments and that high aspect ratio gratings coherently couple to the vibrational transition in the surrounding liquid.

O 52.3 Tue 13:30 P

Infrared-visible sum-frequency generation microscopy of phonon polariton resonances in SiC nanorods — •Sören Wasserroth[1], Richarda Niemann[1], Guanyu Lu[2], Martin Wolf[1], Joshua D. Caldwell[2], and Alexander Paarmann[1] — [1]Fritz-Haber-Institut, Berlin, Germany — [2]Vanderbilt University, Nashville, USA

Sum-frequency generation (SFG) allows the study of surfaces and inversion broken systems. In a new approach we implemented a wide field sum-frequency microscope combining an infrared free electron laser (IR FEL) as excitation source with visible upconversion. The IR FEL provides a powerful, narrow band, and tunable light source [1]. By direct imaging of the SFG light with a microscope in a wide field scheme without scanning the sample or the focus [2], we achieve a spatial resolution well beyond the infrared diffraction limit.

We use SFG microscopy to image phonon polariton resonances in subdiffractional SiC nanorods. Full spectral mapping of the structures allows spectroscopic identification of the various polariton resonances($\sim$ 900 cm^{-1}). Additionally, the high spatial resolution of the microscope resolves the modal structure of polaritons within each nanorod. We follow the evolution of the polariton modes by varying the geometrical parameters of the rods. As we demonstrate here, SFG microscopy presents itself as an excellent novel tool to comprehensively study infrared polaritons in subdiffractional nanostructures.

[1] Schöllkopf et al., Proc. of SPIE (2015)
[2] Kiessling et al., ACS Photonics (2019)

O 52.4 Tue 13:30 P

Broken Symmetry of Surface Phonon Polaritons in Monoclinic β-Gallium Oxide — •Nikolai Christian Passler[1], Tom Folland[2], Joseph Matson[3], Xiang Ni[4], Guangwei Hu[4], Martin Wolf[1], Andrea Alu[4], Mathias Schubert[5], Joshua Caldwell[3], and Alexander Paarmann[1] — [1]Fritz-Haber-Institute of the MPG — [2]University of Iowa — [3]Vanderbilt University, Nashville — [4]City University of New York — [5]University of Nebraska

Materials with low crystal symmetry exhibit correspondingly high optical anisotropy - a critical component for manipulating the propagation, polarization, and phase of light. Specifically, polar crystals with strong optical anisotropy in their surface plane can support in-plane hyperbolic surface phonon polaritons (h-SPhPs), featuring highly directional polariton propagation in the surface plane. So far, the investigated material systems for the observation of h-SPhPs comprise uniaxial and biaxial polar crystals with orthogonal optical axes. Yet, in low symmetry Bravais lattices such as monoclinic and triclinic systems a new class of surface polaritons featuring low symmetry are observed. Here we present Otto-type prism coupling experiments of monoclinic β-gallium oxide demonstrating the intrinsic symmetry breaking of the polariton propagation general to this material class. Furthermore, we present a theoretical approach for the description of polaritons in monoclinic crystals, revealing additional directional symmetry breaking in the polariton propagation patterns. Our results offer significant opportunities for topological photonics, as well as for exploring the anisotropic electronic properties for high power electronic devices.

O 52.5 Tue 13:30 P

Extracting the electronic properties of an oxide two-dimensional electron gas by scanning near-field optical microscopy — •Julian Barnett[1], Marc-André Rose[2], Georg Ulrich[3], Martin Lewin[1], Bernd Kästner[3], Regina Dittmann[2], Felix Gunkel[2], and Thomas Taubner[1] — [1]1. Physikalisches Institut (IA), RWTH Aachen — [2]Peter Grünberg Institut, Forschungszentrum Jülich — [3]Physikalisch-Technische Bundesanstalt Berlin

The interface between bulk insulators $SrTiO_3$ and $LaAlO_3$ (LAO/STO) gives rise to a confined and highly conductive two-dimensional electron gas (2DEG) [1], which poses unique analytical challenges, due to its buried and sensitive nature. Scanning near-field optical microscopy (SNOM) was shown to overcome these challenges by measuring the presence of the LAO/STO 2DEG using highly confined optical near-fields [2], opening the possibility for quantitative analysis by comparison to theoretical predictions. We now introduce spectroscopic s-SNOM measurements of the LAO/STO interface [3], showing that we are able to simultaneously disentangle the 2DEG's optical response and discriminate between thin film and substrate contributions. This is possible by using full spectroscopy, phonon-enhancement, and more accurate modeling based on the Finite Dipole Model, allowing us to set the starting point for a wave of similar spectroscopic investigations on other nanoscale layered interfaces.

[1] A. Ohtomo et al., Nature 427, 423 (2004).
[2] W. Luo et al., Nat. Commun. 10, 2774 (2019).
[3] J. Barnett et al., Adv. Funct. Mater. 30(46), 2004767 (2020).