Mid-infrared dielectric antennas on epsilon-near-zero materials

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Nanoantennas play a major role in light manipulation at the nanoscale thanks to their highly confined and enhanced local fields [1]. The traditional materials of choice for nanoantennas are noble metals, however, there are intrinsic limitations associated with their use. In fact, plasmonic resonances suffer from ohmic losses, affecting the quality factor and the lifespan of the antenna. Moreover, magnetic resonances supported by metallic plasmonic antennas are weak, which is detrimental for specific applications such as those requiring enhanced optical chirality [2]. In the last years, dielectric nanoantennas have been proposed as an alternative to plasmonics. While there are many demonstrations for dielectric nanoantennas working in the visible and near-infrared spectral range [3-5], their extension to the mid infrared (MIR) is not yet fully established. In particular, the epitaxial growth of crystalline semiconductor materials, which are the preferred choices for high-quality dielectric antennas working in the MIR, typically relies on a similar semiconductor substrate, with a refractive index close to the one of the antenna. This environment configuration hinders the establishment of strong resonances for dielectric antennas in the MIR.

In this work, we employ a highly-doped InAs layer [6] as the substrate for an array of MIR dielectric antennas. By varying the doping, we obtain a material showing a zero crossing of the real part of the permittivity, the so-called epsilon-near-zero (ENZ) condition [7], that can be tuned over a broad wavelength range in the MIR. We fabricate an array of dielectric nanoantennas on top of the ENZ substrate exploiting an undoped InAs layer by standard e-beam lithography. By spectrally tuning the localized and lattice resonance frequencies of the antenna array and the ENZ behavior of the substrate, we maximize the local electric field enhancement. We benchmark the platform with a surface-enhanced IR absorption experiment on perfluorooctyltrimethoxysilane (PFTMS) molecules, targeting a vibrational feature at a wavelength around 10 μm and validating the designed resonant behavior. The demonstration of a dielectric platform working in the MIR opens new possibilities in surface-enhanced and chiroptical spectroscopies.

References

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