Multiband Tunable Large Area Hot Carrier Plasmonic-Crystal Photodetectors

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Abstract: We report highly tunable and multispectral photodetectors based on plasmonic hot-carriers, fabricated via a facile, low cost and large area – soft nano-imprinting technique. We provide optical and electrical characterization of our devices to showcase the feasibility of this architecture in optoelectronics including photodetection and light harvesting.

Optical sensing at visible and infrared wavelengths is of paramount importance for a vast number of applications. To accomplish that task, solid-state photodetection has been vastly employed during the last decades, based on semiconductor materials. In semiconductors, the process upon which photons are converted to electrons relies on photon band-to-band absorption, i.e. only photon energies above the bandgap of the semiconductor can be detected [1]. In the last years, a novel metal-based architecture, free from these frequency restrictions, has been proposed that exploits in one hand, the tunable absorption range provided by a nanostructured metal and, on the other hand, the favorable electronic barrier established in the junction of a metal and a semiconductor to separate carriers [2-5]. This makes possible to take advantage of the plasmon decay into electron-hole pairs generating a photocurrent, which will ultimately depend on the absorption of the metal nanostructure itself. Based on that process, visible [2, 3] or IR-sensitive [4, 5] hot carrier devices have been reported, mostly accomplished by complex and costly nanostructuring of the metal, using e-beam nanofabrication techniques. This methodology poses intrinsic problems for scalability and practical applications. A large-area compatible fabrication method, also capable of producing higher performance, is therefore needed in order to fully exploit the advantages of plasmonic hot-carrier devices. In this work we report a multispectral and highly tunable architecture for visible and near-infrared photodetection (see Figure 1). We study the plasmonic and photonic properties of our architecture and by comparing both experimental spectra and FDTD simulations, shed light on the underlying mechanisms responsible for the high degree of tunability of our devices. Our fabrication approach, based on a low cost and large area compatible soft nano-imprinting lithography, facilitates the way for the implementation of this technology in a great variety of optoelectronic devices.

References

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Figures

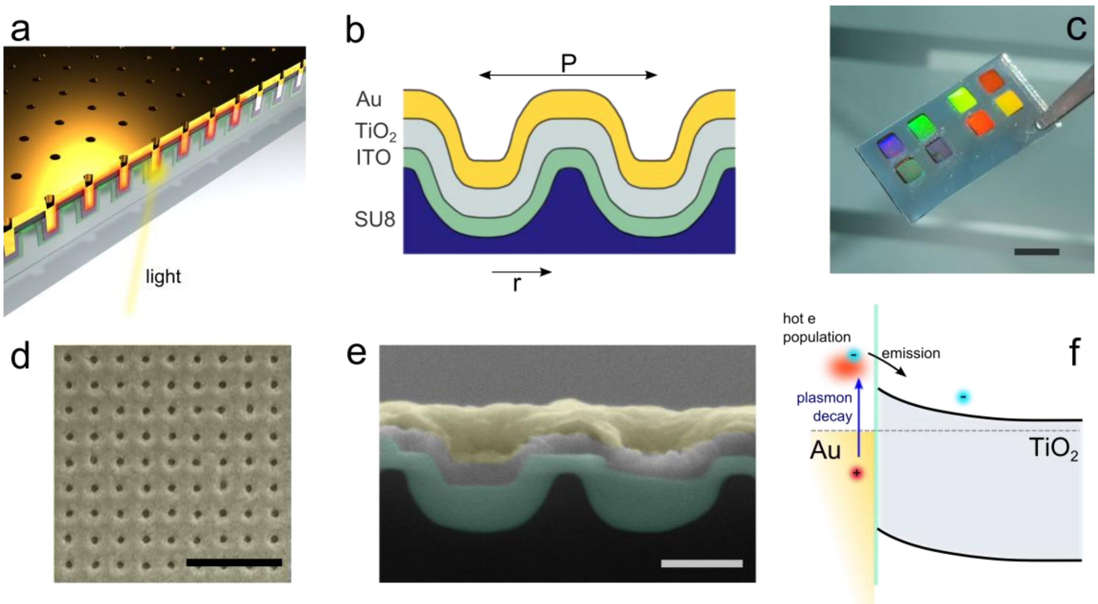

Figure 1: device architecture and principle of operation. (a) Representation of the plasmonic crystal photodetector. Light impinges from the bottom (ITO/glass) exciting resonant modes responsible for the hot electron generation. (b) Schematic of the device architecture: a square array of cylindrical voids in photorresist is coated with 40nm of ITO, followed by 60nm of TiO_2 and 150nm of Au. Different geometries are fabricated varying both lattice parameter (L) and / or the cylinder radius (r). (c) Photograph of a substrate containing eight 9 mm^2 devices; the reflected colors are indicative of the nanostructured metal electrodes. Scale bar is 1 cm. (d) 45º angle view SEM image of the periodic arrays. Scale bar is 2 μm. (e) Cross sectional SEM artificially colored to portray the different layers of the architecture. Scale bar 400 nm. (f) Schematic representation of the photocurrent generation process after light excitation: hot electrons derived from plasmonic damping are emitted over the Au/TiO_2 Schottky barrier into the TiO_2 conduction band.