Metamaterial Perfect Absorber Based Hot Electron Photodetection

Wei Li and Jason Valentine
Department of Mechanical Engineering, Vanderbilt University, Nashville, TN 37212, USA

While the non-radiative decay of surface plasmons was once thought to be only a parasitic process which limits the performance of plasmonic devices, it has recently been shown that it can be harnessed in the form of hot electrons for use in photocatalysis, photovoltaics, and photodetectors. Unfortunately, the quantum efficiency of hot electron devices remains low due to poor electron injection, and in some cases, low optical absorption. Here, we demonstrate how metamaterial perfect absorbers (MPAs) can be used to achieve near-unity optical absorption using ultrathin plasmonic nanostructures with thicknesses of 15 nm, smaller than the hot electron diffusion length [1]. By integrating the metamaterial with a silicon substrate, we experimentally demonstrate a broadband and omnidirectional hot electron photodetector with a photoresponsivity that is among the highest yet reported at telecom wavelengths. We also show how the spectral bandwidth and polarization-sensitivity can be manipulated through engineering the geometry of the metamaterial unit cell. These perfect absorber photodetectors are readily scalable to visible wavelengths and could open a pathway for enhancing hot electron based photovoltaic, sensing, and photocatalysis systems.

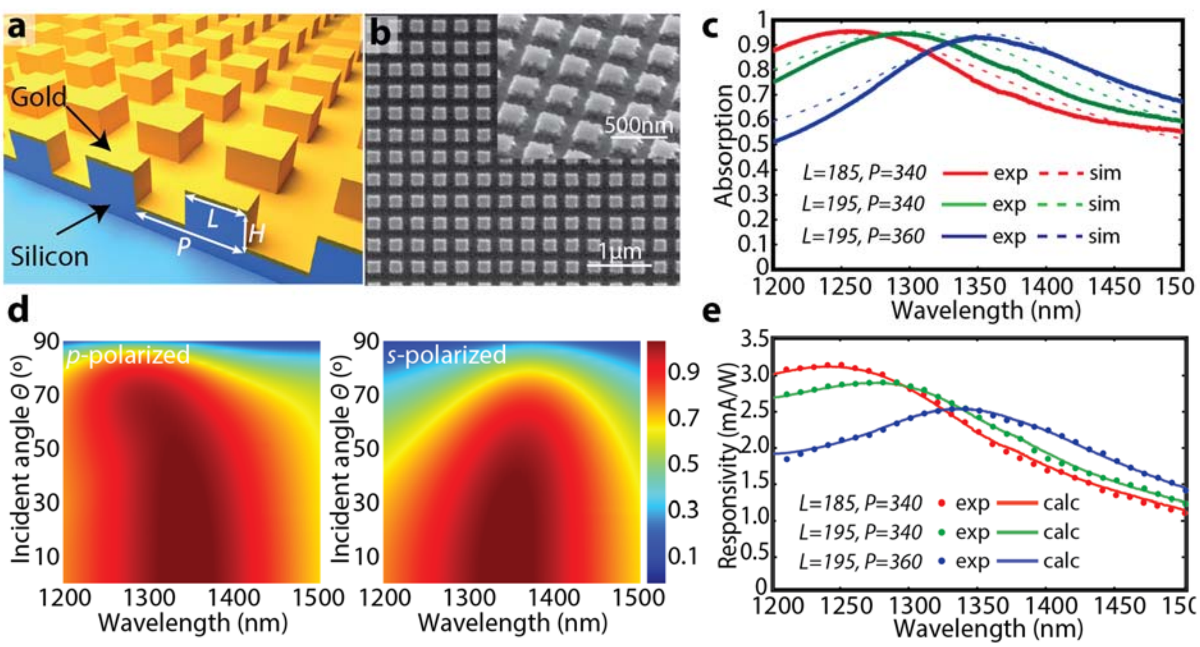

Figure 1. Performance of the MPA-based hot electron photodetector. (a) Schematic and (b) SEM of the device. (c) Optical absorption measurements and simulations for 3 MPAs, all dimensions are in nm and *H* = 135 nm. (d,e) s- and p-polarized absorption demonstrating a low sensitivity to the angle of incidence. (e) Measured and calculated photoresponsivity at zero bias, demonstrating a peak responsivity >3 mA/W at 1250 nm.

References

[1] W. Li and J. Valentine, "Metamaterial perfect absorber based hot electron photodetection.," *Nano Lett.*, vol. 14, no. 6, pp. 3510–3514, 2014.