A Study on the Suitability of Indium Nitride for IR and THz Plasmonics

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Abstract

The desire to manipulate photons in a manner analogous to the control of electrons in solids has inspired interest in topics like localisation of light, plasmonics and near field optics [1]. Metals are the natural choice for plasmonic applications because of their high conductivity. Among metals, silver and gold have been used most often for plasmonic applications due to their relatively low loss in the vaisible and NIR ranges. Recently, interest in plasmonic phenomena has extended beyond the visible spectrum on both sides into the UV and the IR to THz regime [2]. This shift from the natural plasmon resonance frequency of silver and gold has led to a search for new materials that have a plasma frequency more suited to UV or THz part of the spectrum. Semiconductors have a much lower plasmonic resonant frequency than metals, typically in the IR to THz range [3]. This allows semiconductors to confine THz waves to the semiconductor surface (surface plasmon polaritons) and exhibit interesting electromagnetic properties in the THz regime. This paper will look at the potential of semiconductors with inherently high carrier concentration (InSb and InN) as alternative materials for plasmonics in THz to IR range. The advantages and disadvantages of semiconductors are compared with those of conventional metals for plasmonic applications. In particular, the performance of a semiconductor like Indium Nitride is compared with that of Gold as a plasmonic material in the visible (0.7 um) and terahertz (1 THz) regimes. Considering the various irregular geometries and nanostructures that are usually employed in advanced plasmonic applications, a full wave solution of Maxwell's equations is essential. COMSOL Multiphysics being an FEM solver is expected to be better suited for a wider range of geometries as compared to other conventional FDTD solvers. Plasmonic resonances in the visible, IR and THz range are explored in these simulations. Various geometries like gratings and dimer antennas are modelled and the field enhancement in subwavelength apertures are compared for the case of metal and semiconductor. The electromagnetic properties of the metal and semiconductor are simulated using Drude model [3-5]. Gold is shown to be better suited for the visible range and Indium Nitride shows greater field enhancement (~1.3 times that of gold) in the IR and THz regimes.

Reference

[1] Atwater, H. "The promise of plasmonics" Sci. Am. 296, 56–63 (2007)
[2] M. van Exter, and D. Grischkowsky, "Carrier dynamics of electrons and holes in moderately doped silicon," Phys. Rev. B 41(17), 12140–12149 (1990).
[3] M. Ordal, L. Long, R. Bell, S. Bell, R. Bell, R. Alexander, Jr., and C. Ward, "Optical properties of the metals Al, Co, Cu, Au, Fe, Pb, Ni, Pd, Pt, Ag, Ti, and W in the infrared and far infrared," Appl. Opt. 22(7), 1099–1119 (1983)
[4] S. Adachi, "Optical Constants of Crystalline and Amorphous Semiconductors: Numerical Data and Graphical Information," Springer-Verlag, (1999).
[5] A. B. Djurisic and E. H. Li, "Modeling the optical constants of hexagonal GaN, InN and AlN", J. Appl. Phys. 85, 2848 (1999)

Figures used in the abstract

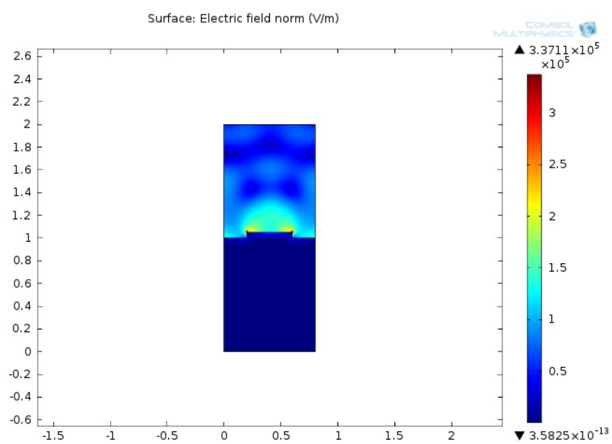

Figure 1: Surface plasmons in grating.

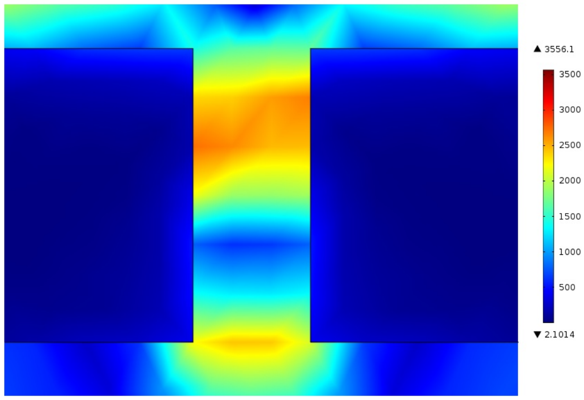

Figure 2: Field enhancement in the gap of a dimer antenna.