Infrared Dipole Antenna Enhanced by Surface Phonon Polaritons

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It is well-known that surface plasmon polaritons (SPPs) are electromagnetic waves propagating along the interface between a metal and a dielectric at the visible and near infrared wavelengths. Recent advances in nanofabrication techniques have enabled the realization of a wide variety of metallic nanostructure shapes and sizes, which have received considerable attention for their ability to guide and manipulate SPPs at the nanoscale. At mid-infrared regime, the plasmonic response of metal is either far weaker or nonexistent and SPPs propagation constant (β) is close to free space wave vector (k_0) at the light line. Most recently, it has been introduced that SPPs have a counterpart in the mid-infrared regime, which is the so-called surface phonon polaritons (SPhPs). SPhPs arise from the coupling of the electromagnetic field with the lattice vibrations of polar dielectrics at the infrared frequencies.[1]

Silicon carbide (SiC) is a material that has negative dielectric permittivity in the mid-infrared region, typically between 10.3 and 12.6 μm.[2] This characteristic allows SPhPs to be excited in SiC crystals. In this study, we numerically investigate the integration of traditional dipole antenna with the resonant excitation of SPhPs (Fig. 1). Resonant optical antenna can confine strongly optical near field in a subwavelength volume and the geometry of the antenna powerfully influences its optical properties, particularly in field confinement. In simulation, we use 10.6 μm incident infrared radiation from CO_2 lasers. The dielectric permittivity of gold and SiC at this wavelength is $\varepsilon_{Au} = -3128.7 + 1558.8i$ and $\varepsilon_{SiC} = -1.15 + 0.13i$, respectively. Fig. 2 shows the intensity enhancement in the gap region of gold dipole antennas on SiC and Si substrates. The intensity enhancement in free standing infrared antenna and dipole antenna on SiC substrate at 10.2 μm (no SPhPs excitation) are also plotted in Fig. 2. Due to the synergistic action of the dipole antenna and the resonant excitation of SPhPs, field enhancement in the gap region can reach a value that is more than four orders of magnitude higher than that of free standing dipole antenna. This giant field confinement is expected to find promising applications in biomolecule sensing and highly sensitive infrared photodetectors.

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[1] S. A. Maier, *Plasmonics: Fundamentals and Applications* (Springer, New York, 2007) p. 101

[2] N. Ocelic and R. Hillenbrand, Nat. Mater., **3**, 606 (2004)

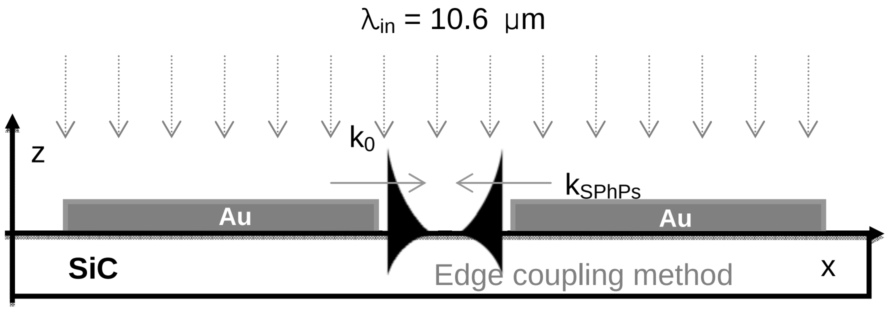

Fig. 1. Schematic diagram of an infrared dipole antenna enhanced by surface phonon polaritons.

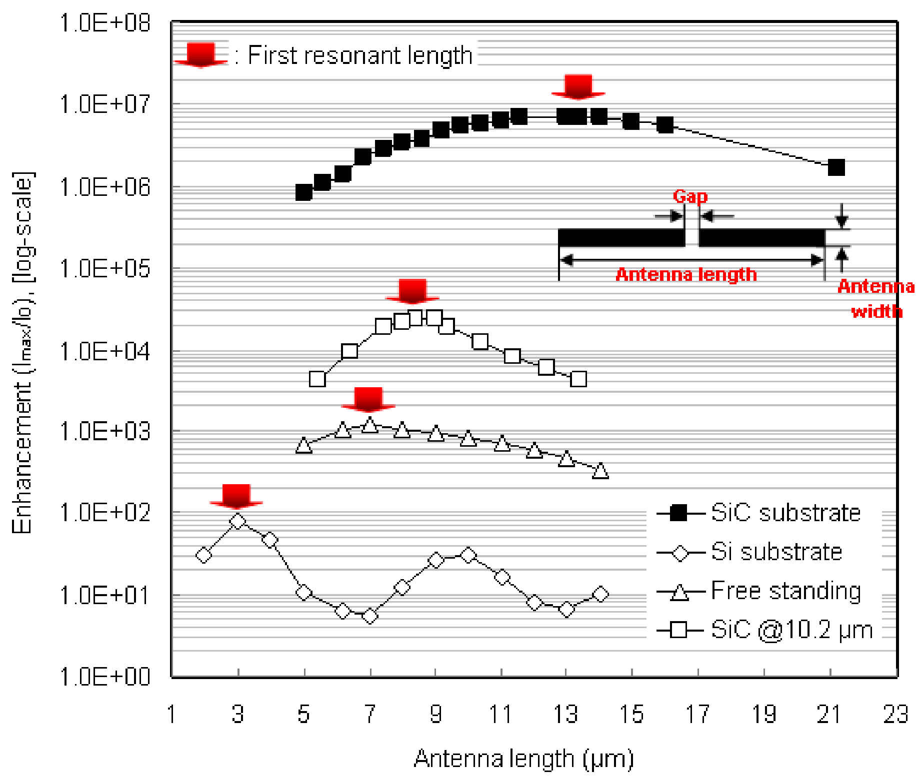

Fig. 2. Intensity enhancement in free standing infrared antenna and infrared antennas on SiC and Si substrates at 10.6 μm. Intensity enhancement in infrared antenna on SiC substrate at 10.2 μm is much lower because no SPhPs can be excited at this wavelength.