Strong magnetic field concentration in arrays of thick gold nanorings

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We show that the coupled-bonding plasmon resonance in coupled gold nanorings changes its character from electric to magnetic when increasing the height of the nanorings, giving rise to magnetic plasmons in the near infrared regime. Numerical simulations show that a virtual current loop appears at resonance for sufficiently thick nanorings (> 250 nm), causing a strong concentration of the magnetic field in the gap region (magnetic hot spot). There is an optimum thickness over spacing ratio that provides the maximum magnetic intensity enhancement (over 100-fold) and give an explanation of this observation. A red-shift of the plasmonic resonance is observed when the nanorings height is increased, which is confirmed both numerically and experimentally for arrays of coupled nanorings built on quartz substrates. Our structure works as an array of magnetic nanoantennas. The arrangement in an array will provides a very dense periodic structure of magnetic hot spots (about 500 million per cm^2 in the fabricated samples) when illuminating the nanorings with unpolarized light at the resonant wavelength. Each nanoantenna will be formed by two closely-spaced nanorings whose performance mimics a magnetic nanoloop. Indeed, a loop antenna is at resonance at a wavelength equal to its perimeter. In our case, the resonance (see Fig. 2(c)) occurs at wavelength about 1.5-2 times the perimeter (obtained as $2s+2t$). However, this can be explained by the penetration of the fields inside both the metal and the dielectric substrate, which is well-known to produce an increase in the wavelength of the LSPR, as in the case of dipole nanoantennas. Therefore, we argue that our structure performs as an array of resonant nanoloop antennas. The nanoring arrays could be used to build optical metamaterials as well as to observe a large variety of magnetic-based plasmonic effects at optical frequencies.

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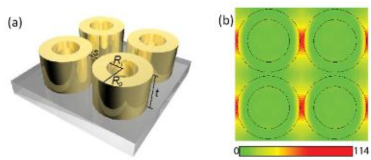

Figure 1: Transmission through an array of square holes in a silver screen at oblique incidence. Square periodicity is 1µm. Size of the holes is 250 nm and thickness of the screen is 50 nm. Wood's frequencies (fw) range from 150 THz to 220 THz. The metal is modeled by a Drude Lorentz permittivity. Solid lines correspond to the mode matching model and dashed lines to CST simulations.

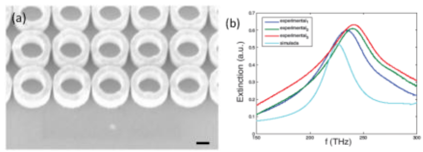

Figure 2: (a) SEM image of a fabricated sample with t = 325 nm and s = 30 nm (scale bar 200 nm). (b) Measured spectra of a three fabricated samples and comparison with a numerical result obtained by CST Microwave Studio (R_o = 300 nm, R_i = 200 nm, t = 350 nm, s = 60 nm; substrate: quartz).