Fabrication and Tuning of Nano-scale Metallic Ring and Split-ring Arrays

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Metallic structures with dimensions smaller than the wavelength of light demonstrate fascinating optical properties which depend strongly on the nano-particle size, shape and interparticle spacing. The optical properties are caused by the excitation of localised surface plasmon resonances, which lead to strong enhancement and confinement of the optical field and can be exploited for many applications including Surface-enhanced Raman Spectroscopy (SERS), near-field scanning optical microscopy, and negative refractive index materials.

In order to fully exploit the properties of these structures, both a highly reproducible and flexible fabrication technique as well as an in-depth understanding of the optical properties is needed. In this paper we demonstrate the fabrication of arrays of gold rings and split-rings on glass slides using electron beam lithography (Figure 1). E-beam lithography allows not only precise control of the size, shape and spacing of the arrays, but also the scope to design novel shapes at will. Rings with dimensions down to 70nm radius, wire widths of 35nm and gaps of 60nm were routinely fabricated.

We characterise these arrays using polarisation dependent absorption spectroscopy. The structures can support multiple plasmon resonances, demonstrating that excellent uniformity across the array is achieved. These resonances are further characterised using a finite difference time domain (FDTD) method to model the electric field distribution around the ring structures (Figure 2).

We also investigate how changing the size of the gap in the split-ring structures affects the optical properties of the structures. We find that the gap can be used to tune the resonances over more than 500nm (Figure 3). The potential of these structures to be used as surface plasmon based sensors is discussed.

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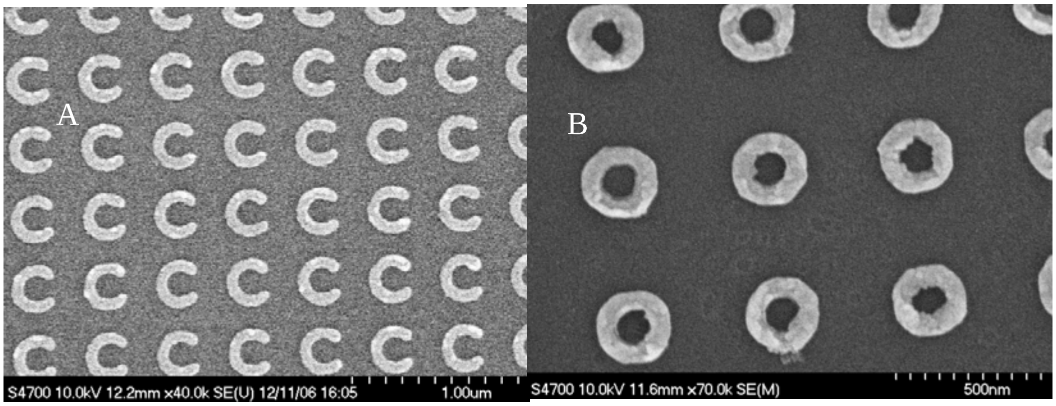

Figure 1. SEM images of 135nm radius a) split rings and b) complete rings

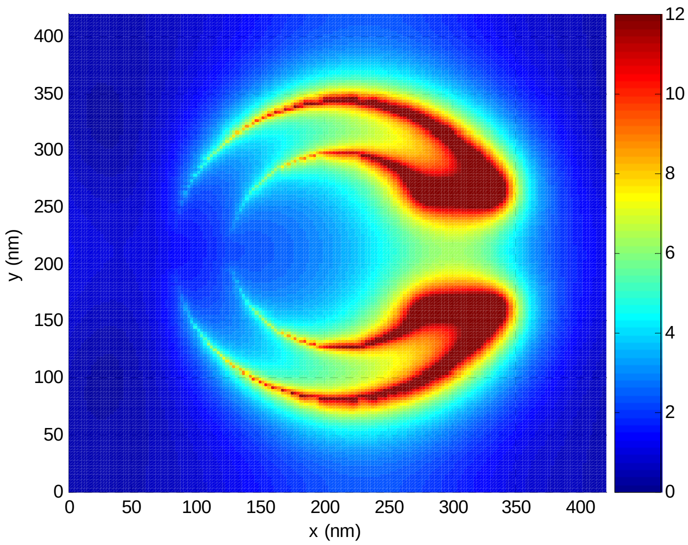

Figure 2. Normalized electric field distribution for the first order mode for a 135nm radius split ring with a 100nm gap at a wavelength of 2500nm.

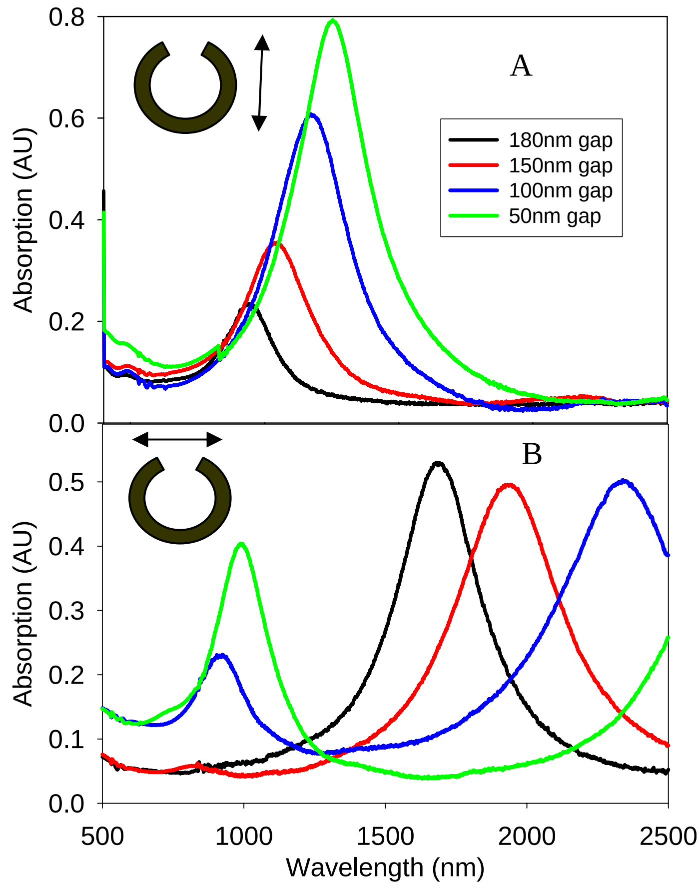

Figure 3. Absorption spectra for 135m radius split rings with varying gaps for an electric field a)perpendicular and b)parallel to the gap.