Metamaterials Constructed by Erected-type Split Ring Resonators

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Split ring resonators (SRRs) could be approximately regarded as an equivalent LC-oscillator and coupled with incident light at its eigen-frequencies. With time-varying magnetic field component of incident light perpendicular to the SRR plane, the induced currents circularly flow in the metallic loop and generate an induced magnetic field counteracting the incident magnetic field, which procures a variation in permeability and impel SRRs as a significant magnetic meta-atom. After the first experimental demonstration of negative refraction index metamaterials (MMs) in microwave regime, which drove the theory into reality, the expanding researches for broader applications turned to develop SRRs at higher frequency and thus focused on creating smaller and three-dimensional (3D) SRRs. Several but rare techniques were reported to assemble 3D SRRs in infrared or optical frequency, in which the fabrication processes were relatively complicated or required a state-of-art facility.

In this work, we present several kinds of MMs constructed by 3D SRRs in which the stereostructure were assembled form two dimensional (2D) templates by a bilayer metal stress driven self-folding technique. The 2D template consists of two arms and a connection pad which was purposely designed with wider width comparing to the arms and served as an adhesive area during self-folding process. A desired self-folding of arms was carried out by means of a bilayer residual stress in which the top Au film reveals higher tensile stress while the arms were released from Si substrate during dry etching process, as shown in Fig. 1.

Figure 2 exhibits the SEM micrographs of constructed MMs by 3D SRRs inclusive of anisotropic-, isotropic-, and toroidal- MMs. A Fourier transform infrared spectroscopy (FTIR) is employed for the characterization of transmittance spectra. The calculated transmittance spectra and the corresponding field patterns were accomplished through COMSOL multiphysics but not shown in this abstract.

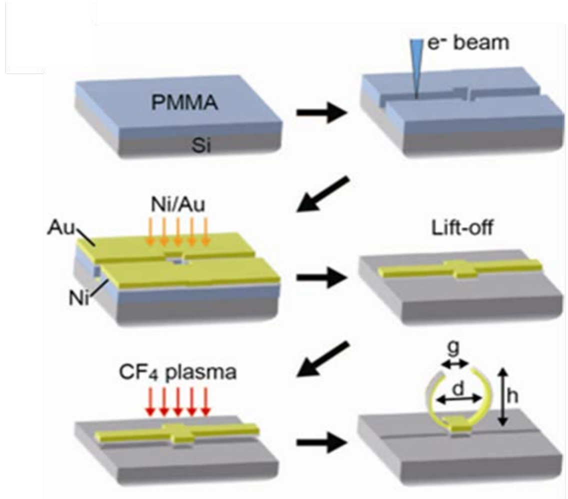

Figure 1: The fabrication process of a 3D SRR: spin-coating resist, electron beam lithography, Ni/Au (10/60 nm) deposition, lift-off, CF_4 plasma dry-etching, and self-folding in sequence. The SRR diameter, *d*, height, *h*, and gap size, *g*, were 2.2 µm, 1.8 µm, and 1.5 µm, respectively. Note that shadow effect of the arms in the dry-etching process produces protruding Si portions under the arms in the last two steps.

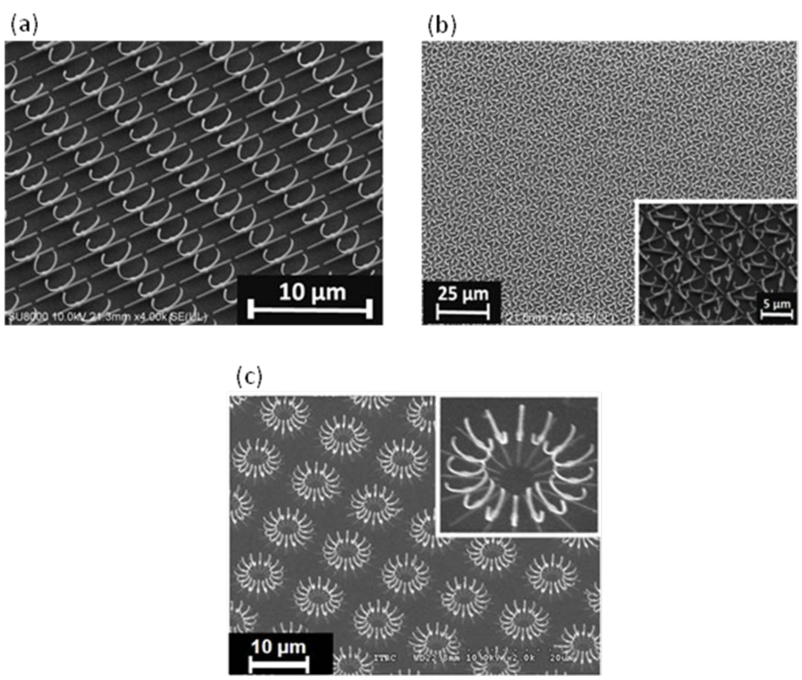

Figure 2: Metamaterials constructed by 3D SRR: (a). anisotropic metamaterials (b) isotropic metamaterials (c) toroidal metamaterials.