Au split-ring resonator arrays responsive to a magnetic field in a visible frequency region fabricated by UV nanoimprint lithography

Takuya Uehara[1], Tatsuya Tomioka[1], Shoichi Kubo[1],
Morihisa Hoga[2], and Masaru Nakagawa[1,3]
[1]*IMRAM, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai, Miyagi 980-8577, Japan*
[2]*Research & Development Center, Dai Nippon Printing Co., Ltd., 250-1 Wakashiba, Kashiwa, Chiba 277-0871, Japan*
[3]*JST-CREST*
nakagawa@tagen.tohoku.ac.jp

Metamaterials have attracted much attention due to their unique optical properties such as negative refractive indices [1]. In particular, split-ring resonators (SRRs) are promising structures to induce oscillation of free electrons causing the changes in permeability by responding to a magnetic field of incident light [2, 3]. We have recently fabricated Au SRR arrays with a 50-nm-wide line and two 40-nm-wide gaps by reactive-monolayer-assisted thermal nanoimprint lithography, which showed a unique response to a magnetic field of incident light centered at a visible wavelength of 690 nm [4]. In this study, we intended to fabricate similar Au SRR arrays by UV nanoimprint lithography for patterning at larger area at adequate throughput.

As shown in Fig. 1(a), a replica resin mold was made with glycerol 1,3-diglyrolate diacrylate (GDD) on a silica substrate by UV nanoimprinting using a fluorinated silicon master mold having SRR arrays at a 5-mm square area. A cleaned Au-plated substrate (Au 10 nm/ Cr 5 nm/ silica) was modified with a hydroxyl-terminus monolayer of 8-mercapto-1-octanol. Figure 1(b) shows the schematic illustration of the method for preparing Au SRR arrays. A GDD-based resin (NL-SK1F) and a bisphenol A-based resin (NL-KK1F) were used as UV-curable resins. The spincoated resin film was transformed on the modified substrate by UV nanoimprinting using a fluorinated replica resin mold. Au SRR structures were obtained by Ar ion milling, VUV exposure, and Cr wet etching.

Au-plated substrates modified with the hydroxyl-terminus monolayer allowed the coating and molding of 0.03-μm-thick UV-curable resin films, while many defects due to resin dewetting occurred on unmodified substrates. Fig. 2 shows SEM images of Au SRR arrays. In the case of NL-SK1F, the line width of Au SRR arrays was approximately 20 nm, which was much smaller than that of approximately 50 nm in the case of NL-KK1F. The UV-curable resin of NL-KK1F was available for the fabrication of Au SRR structures more precisely. The optical properties in a visible frequency region and the multiple patterning in a step-and-repeat manner will be demonstrated.

[1] R. A. Shelby *et al.*, Science **292**, 77 (2001).
[2] J. B. Pendry *et al*., IEEE Trans. Microwave Theory Tech. **47**, 2075 (1999).
[3] A. Ishikawa *et al*., Phys. Rev. Lett. **95**, 237401 (2005).
[4] T. Tomioka *et al*., submitted.

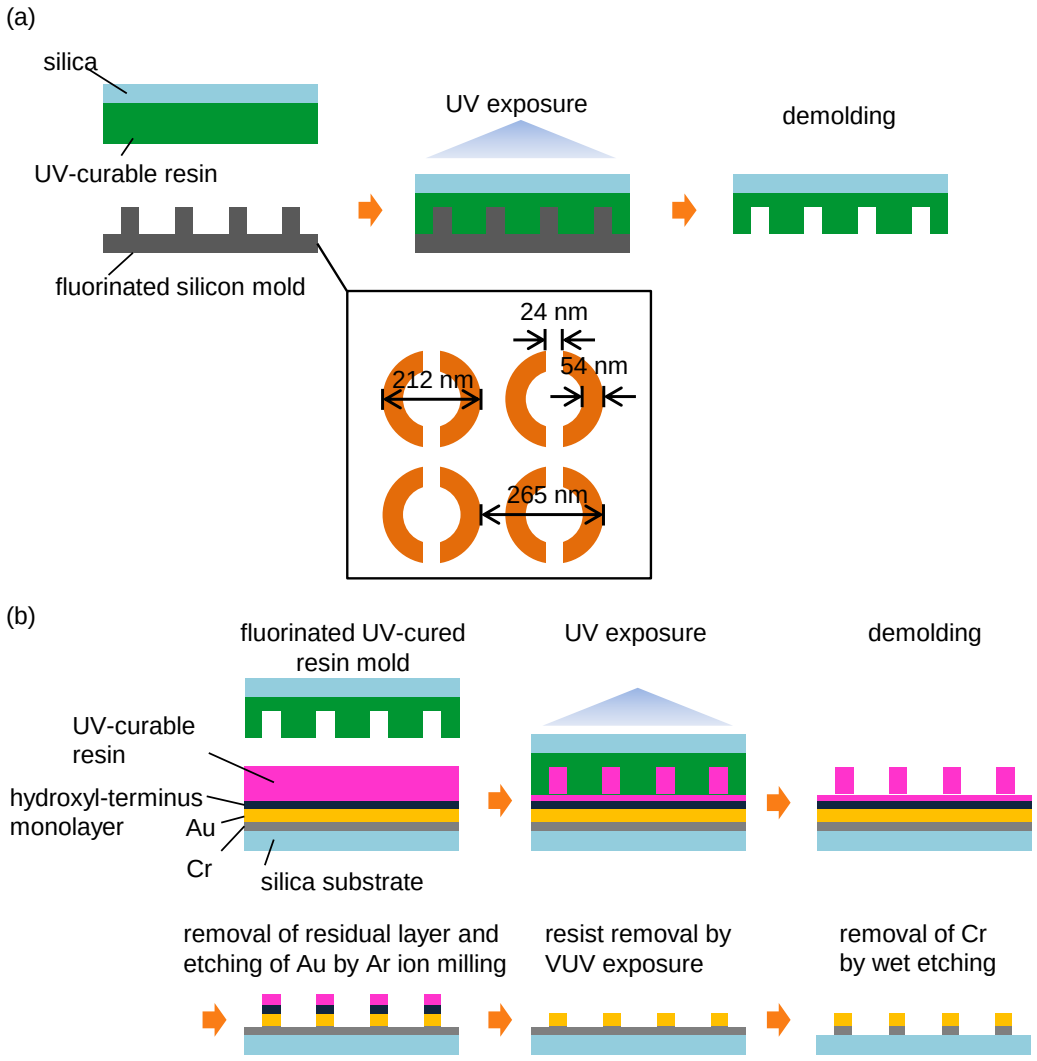

Fig. 1. Schematic illustration of the method for preparing (a) a replica resin mold and (b) Au SRR arrays on a silica substrate by UV nanoimprint lithography. The inset in Fig. 1(a) shows the design of a used master mold.

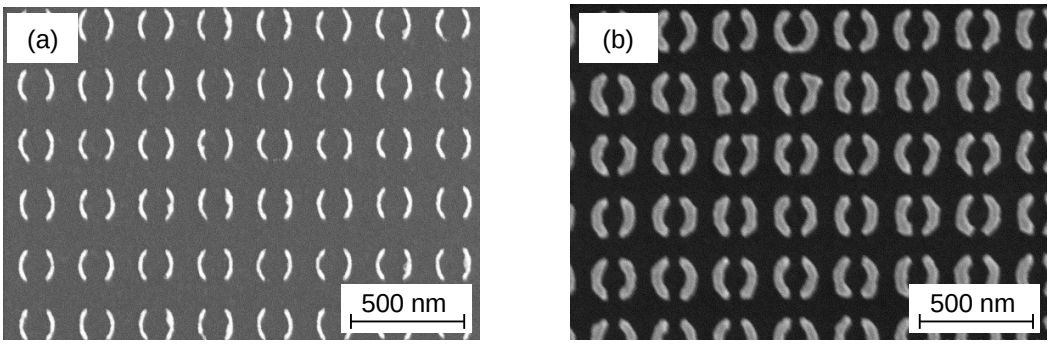

Fig. 2. SEM images of Au SRR arrays fabricated with a UV-nanoimprinted resist layer of (a) NL-SK1F and (b) NL-KK1F.