Sub 100 nm Pattern Transfer from Self-Assembled Silica Nanoparticles Grafted with Polymer Brush on Patterned Substrate

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Colloidal lithography is one of the promising methods for large-area, low-cost fabrication of ordered periodic nanostructures that are expected to be suitable for biomedical devices, photonic devices, and semiconductor devices [1]. With conventional lithography techniques, it is difficult to form sub 100 nm hexagonal dot pattern at a narrow pitch. In contrast, self-assembled nanoparticles easily realize sub100 nm hexagonal dot pattern although for the non-close packed hexagonal ordering some spacer material or an additional process is needed. We have selected polymer brush grafted to surface of nanoparticles as a spacer for non-close-packed hexagonal ordering. We have formed well-ordered single layer of polymer grafted SiO_2 particles on Si substrate and successfully transferred the non-closed pack hexagonal dot pattern to the substrate [2]. With regard to particle assembly, the issue is the control of ordering direction and position in the substrate.

In the present work, we investigated the domain-controlled assembly of polymer-grafted silica particles on physical guide structure to realize the sub 100 nm pattern size. The silica particles with a diameter of about 50 nm were surface-modified with polymethyl methacrylate (PMMA) by reversible addition–fragmentation chain transfer polymerization. The assembled pitch of the particles is about 84 nm on flat substrate with the PMMA molecular weight of about 2.0 kg/mol. The process flows of guide structure and pattern transfer to the substrate are shown in Fig.1. The guide structure is C (30 nm)/Si (3 nm) stacked film deposited on Si substrate and the wide-pitch hexagonal hole pattern was formed by electron-beam lithography. The particles are ordered on the small hole by the coating process. Figure.2 shows SEM top-view images of fabricated guide pattern, assembled particles on guide structure and pattern transferred to the substrates from assembled particles. The diameter of guide hole is about 30 nm and the pitch is designed to be 84 nm. The standard deviation of the hole pitch is about 1.5 nm and C.V. value is about 1.8%. The standard deviation of the particle pitch is about 1.8 nm and C.V. value is about 2%. The transferred pattern showed almost the same value to the assembled particle. We realized the sub100 nm narrow-pitch pattern transfer with the control of ordering direction and position of the particle mask by the guide structure in wide area of over 1μm^2.

[1] J. Boneberg, F. Burmeister, C. Schafle, P. Leiderer, D. Reim, A. Fery, and S. Herminghaus, Langmuir. 13 (1997), 7080
[2] T. Sawabe, A. Watanabe, N. Kihara, R. Yamamoto, and K. Ohno, EIPBN, (2016), P-81.

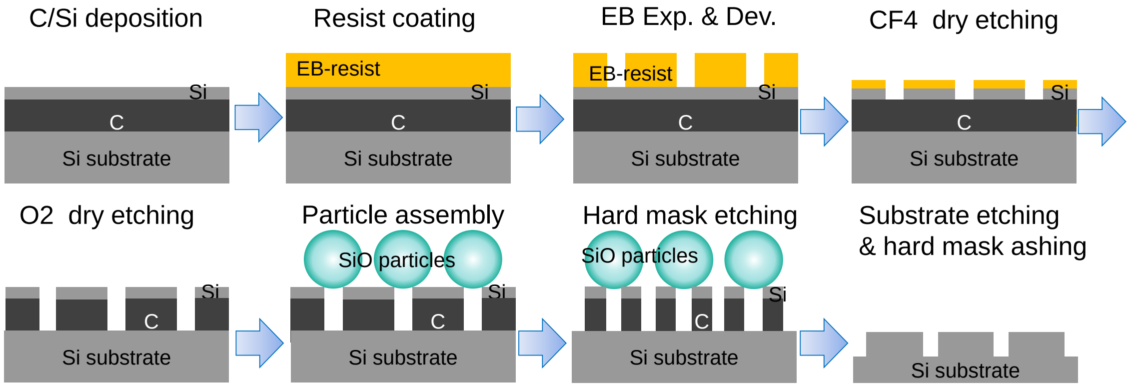

Fig.1 Schematic view of process flow for the pattern transfer and fabricated guide structure

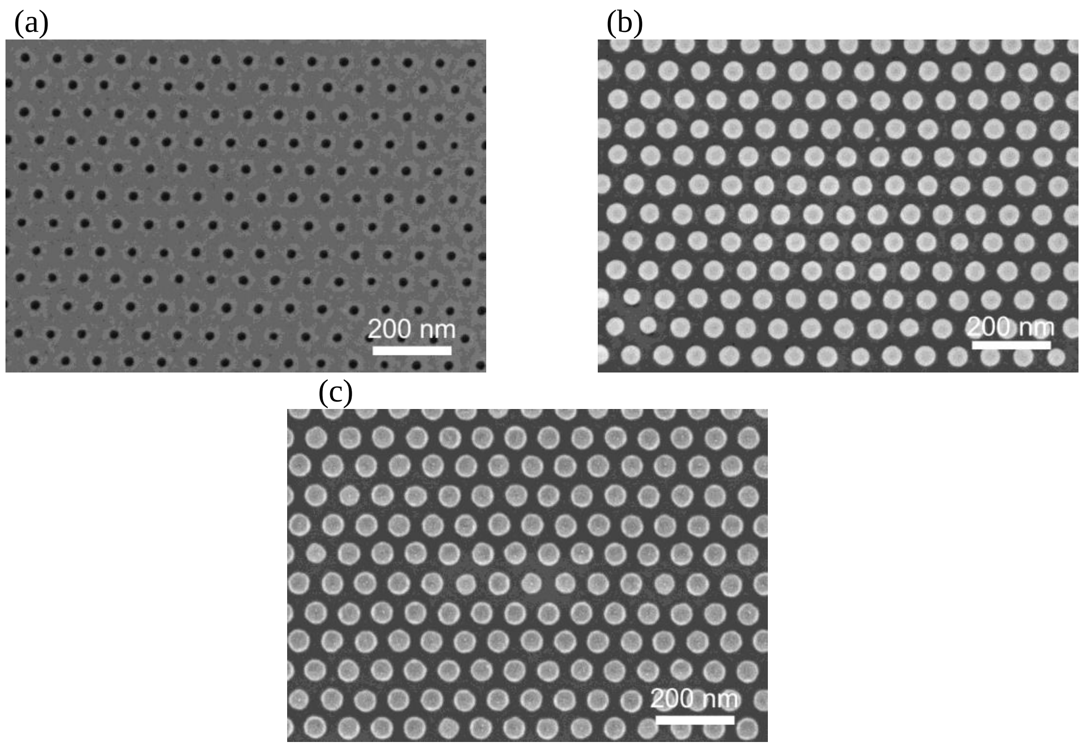

Fig.2 SEM top views of (a) guide structure, (b) assembled particles after PMMA etching and (c) pattern transferred from assembled particles to the substrates. The guide hole diameter is about 30 nm and the hole pitch is 84 nm. The ordering pitch of PMMA-etched silica particles is about 84 nm which is consistent with the ordering pitch of silica particles grafted by PMMA with molecular weight of 2.0 kg/mol on flat substrate. The pattern transferred from assembled particles revealed almost the same pitch and standard deviation.