Local nanopatterning using PS-b-PMMA block copolymer self-assembly/electron beam combined lithography

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In order to achieve the simple process for the positional selective fabrication of nanostructures, a lithography process which combined a block copolymer self-assembly and electron beam (EB) lithography has been researched. This process is carried out by using characteristics as an EB resist of polystyrene (PS) and polymethyl methacrylate (PMMA) in PS-b-PMMA. Thus far, although a fabrication of a negative-tone nanoporus structures had been performed[1], there is a possibility that it enables us to fabricate various other nanostructures. And the pattern formation characteristics has not been evaluated sufficiently yet. Therefore, nanostructure fabrication using a lamellar structure was tried for line structure in this study. Fabrication of both of positive- and negative-tone pattern was performed and their pattern formation characteristics were evaluated.

Figure 1 shows a schematic of the nanopatterning process performed in this study. First of all, PS-b-PMMA perpendicular lamellar structure was fabricated on the Si substrate with a PS-r-PMMA (5.3 kg/mol), as shown in Fig. 2. PS-b-PMMA with a molecular weight of 18-18 kg/mol was used. Heating temperature and time are 230 deg. C and 1 h. Then, we tried to fabricate locally both of positive- and negative-tone patterns by directly-exposing PS-b-PMMA lamellar structure using EB. 50 kV EB with a beam current of 1 nA was used. In the case of positive-tone pattern fabrication, an exposed pattern was developed by the mixture with which isopropyl alcohol (IPA) and water (Mixing ratio: 7:3). Figure 3(a) shows an example of a local positive-tone structure formed by EB exposure. Positive-tone pattern was formed clearly at dose of over 400 $\mu C/cm^2$, as shown in Fig. 3(b). And also, we tried the formation of the negative-tone pattern, as shown in Fig. 1. In this process, *o*-xylene was used as a developer. As a result, a negative-tone pattern also locally-formed as shown in Fig. 4(a). As shown in Fig. 4(b), a self-assembled PS film was completely exposed with a dose of 6.0 mC/cm^2 or more. Even if PS and PMMA assemble as a lamellar structure, they do not lose their function as EB resist. In this study, we demonstrated that the both of positive- and negative-tone nanopattern could be locally-formed by very simple process. By using the self-assembled PS-b-PMMA film with controlled orientation, the requirement for resolution of lithography will be low. Therefore, it seems that the method in this study is effective as a means for fabricating a nanostructure locally. Formation characteristics of nanostructures such as influence of processing conditions will be reported in detail.

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[1] H. Suzuki, R. Kometani, S. Ishihara, S. Warisawa: Abstract of EIPBN2012, 10B-04 (2012).

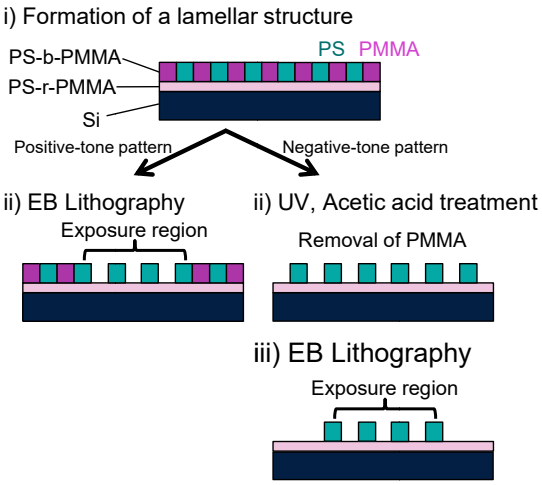

Figure 1: Schematic of a local nano-pattering using self-assembly/electron beam combined lithography for positive- and negative-tone pattern

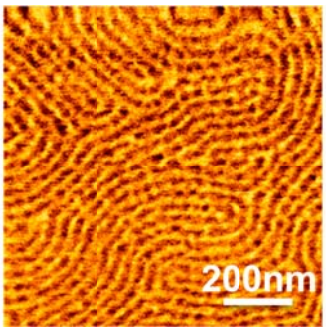

Figure 2: Atomic force microscope (AFM) phase image of a PS-b-PMMA perpendicular lamellar structure.

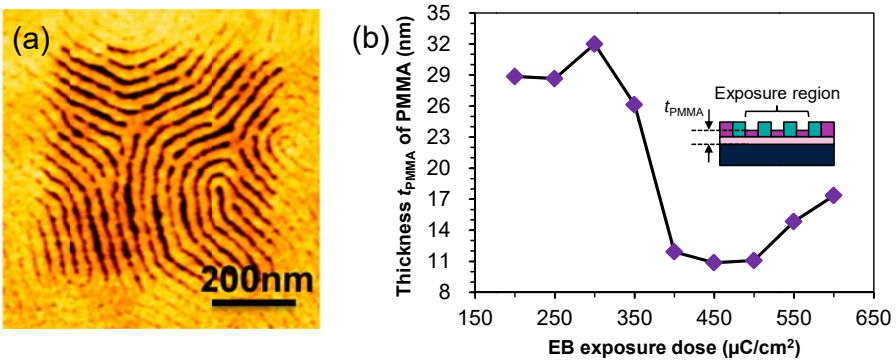

Figure 3: Fabrication results of a positive-tone pattern: (a) AFM topographic image of a nanostructure locally-formed by EB exposure with dose of 400 μC/cm^2, (b) Relationship between EB exposure dose and thickness t_{PMMA} of PMMA. t_{PMMA} was measured by scanning electron microscope.

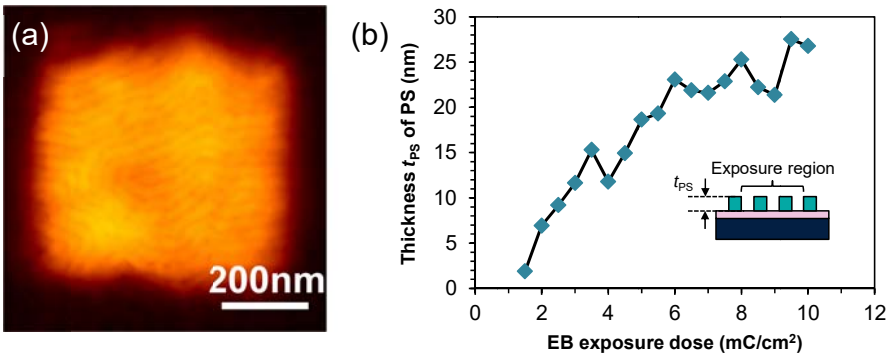

Figure 4: Fabrication results of a negative-tone pattern: (a) AFM topographic image of a nanostructure locally-formed by EB exposure with dose of 9.5 mC/cm^2, (b) Relationship between EB exposure dose and thickness t_{PS} of PS after development. t_{PS} was measured by AFM.