A gradually shifted surface plasmon resonance with a controlled diameter of a nano-hole structure by self-assembly technique

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A surface plasmon resonance (SPR) on a metal nano-structure is expected to various applications such as bio-sensors and optical communication devices. However, the area of SPR devices is limited due to the difficulty in fabricating small periodic structures in large area. Furthermore, common SPR devices utilize only single resonant wavelength. To expand a potential of SPR applications, a new type of SPR device applicable to varied resonant frequency will be proposed as shown in Figure 1(a). In this study, for realizing such SPR devices with large area, we tried to control a diameter of a self-assembled nano-hole structure with mixing polymers and controlling thickness. We also tried to prove a peak shift of SPR wavelength using the nano-hole structures with a different film thickness.

We mixed two types of block copolymers: PS:PMMA = (1) 50:21 (kg/mol) and (2) 163.5:67.5 (kg/mol). They were annealed and self-assembled to form PS nano-hole structure. Figure 1(b) shows the fabricated results of PS nano-hole structure, on which the silver thin-film was deposited at 45° of an incident angle. The thickness of the silver layer was 50 nm. Figure 2 shows a variation result of a hole density and a hole diameter against polymer film thickness. In the case of single block copolymers, the ratio was drastically decreased and the diameter was not changed in proportion to the film thickness. In contrast, in the case of the mixed block copolymer, the ratio was almost constant and the diameter was changed in proportion to the film thickness. The linear change of the diameter with the constant ratio is effective in controlling a SPR wavelength shift. Figure 3 shows the SPR characteristics. We fabricated the nano-hole structures with different diameter controlled by a film thickness, and measured reflection intensities of each structure. In the case of the unmixed block copolymer, SPR spectrum was not changed linearly in Figure 3(a). In contrast, in the case of the mixed block copolymer, SPR spectrum was gradually varied from 377 nm to 385 nm while the polymer film thickness was increased in Figure 3(b).

In conclusion, we demonstrated that a diameter of self-assembled nano-hole can be controlled by changing a film thickness of a mixed block copolymer. We also showed that SPR wavelength shift can be controlled by the nano-hole structure with diameter controlled by the film thickness. We believe that this device has a potential to expand SPR devices. In future, we will develop SPR devices using this fabrication technique.

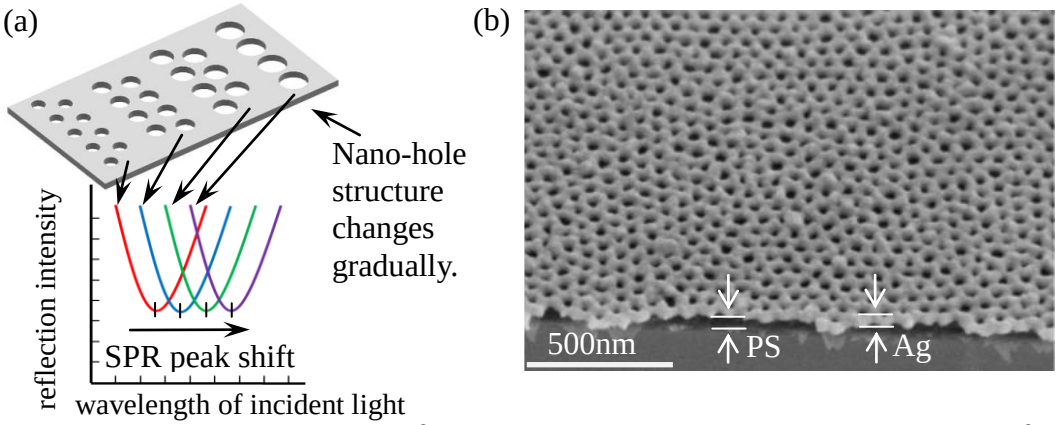

Fig. 1. (a) A schematic image of our proposed SPR device. (b) A SEM image of the fabricated nano-hole structure for the SPR device: A mixed block copolymer of PS-b-PMMAs were self-assembled to form PS nano-hole structure. The nano-hole structure was coated with a silver thin-film.

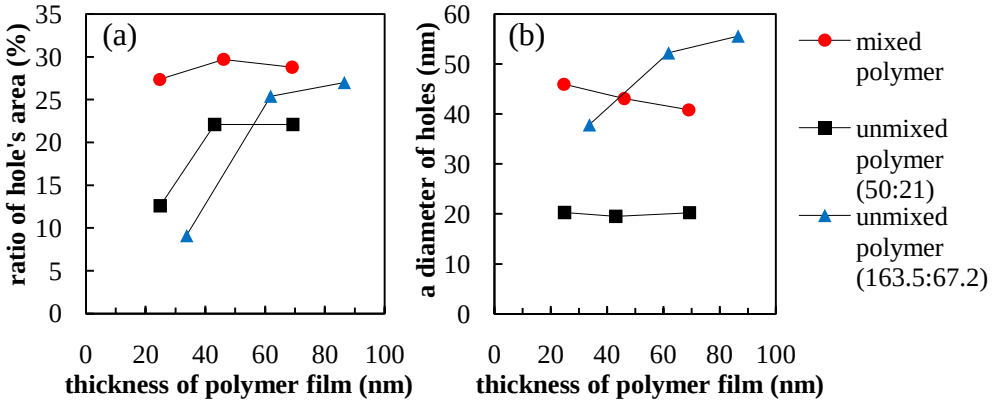

Fig. 2. (a) Ratio of hole's area against polymer film thickness.
(b) A diameter of hole against polymer film thickness.

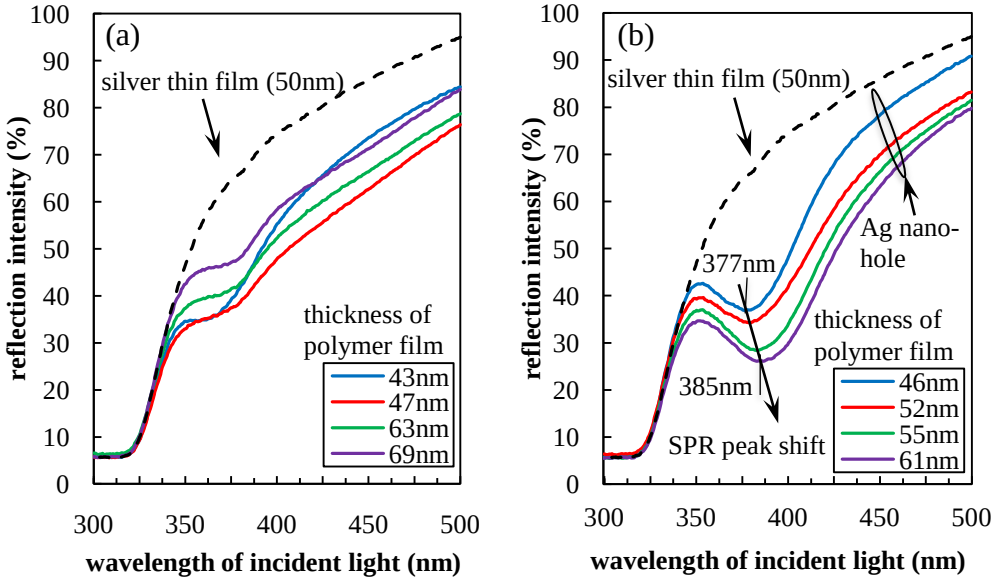

Fig. 3. Reflection intensity of SPR devices using (a) unmixed polymer's nano-hole structure (b) mixed polymer's nano-hole structure