Broadband antireflective properties of plasma modified benzoxazine films

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Low-cost and high-performance antireflective surfaces and coatings are useful for optical applications, such as solar cells. Because of high refractive index of silicon, the reflectance losses up to 40% severely limiting the performance of silicon-based photon sensitive devices. The reduction of surface reflection is necessary in the working wavelength regime. Previously, we reported a new class of nonfluorine, non-silicon low surface free energy polymeric material: polybenzoxazine. [1-2] The polybenzoxazine possesses a surface free energy ($\gamma = 16.4$ mJ/m^2) that is even lower than that of pure poly(tetrafluoroethylene) (PTFE) ($\gamma = 21$ mJ/m^2). Furthermore, polybenzoxazine also possess unique properties such as low cost, a high glass-transition temperature (Tg), [3] superior mechanical properties, [4] excellent resistance to both chemicals [5] and UV light, [6] and a low degree of water absorption. [4] In this work, broadband antireflective properties of the plasma modified benzoxazine films are presented.

Benzoxazine film on silicon wafers were performed with a simple three-step process as shown in Fig. 1. Firstly, BA-m benzoxazine dissolved in tetrahydrofuran (50 mg·mL^{-1}) was spin-coated onto a silicon wafer. Secondly, Ar plasma roughening of the benzoxazine monomer thin film was performed in a reactive ion etching (RIE) system (TEL, model TE5000). Finally, cross-linking of these plasma-roughened benzoxazine films was performed by placing them onto a digital hot plate for 1 h at 200°C. Fig. 2 shows the reflectance spectra of benzoxazine surfaces with various Ar plasma treatment time. The reflectance spectrum of benzoxazine film without Ar plasma treatment shows a thin-film behavior. After plasma treatment, the reflectance spectra are reduced below 5% in the wavelength range from 200 nm to 1000 nm. The antireflective performance is better for a shorter plasma treatment time. The morphologies of benzoxazine surfaces was observed using AFM as shown in Fig. 3. The benzoxazine films exhibit rugged surfaces possessing papillae-like structures. The dimension of the papillae increases upon increasing the plasma exposure time. In this study, we have developed low-cost and high-performance broadband antireflective surfaces. Detailed analyses and results will be reported in the conference.

1. C.F. Wang, Y.C. Su, S.W. Kuo, C.F. Huang, Y. C. Sheen, F.C. Chang, Angew. Chem. Int. Ed. **45**, 2248-2251 (2006).
2. C.F. Wang, S.F. Chiou, F.H. Ko, C.T. Chou, H.C. Lin, C.F. Huang, F.C. Chang, Macromol. Rapid Commun. **27**, 333-337 (2006).
3. H. Ishida, H.Y. Low, Macromolecules **30**, 1099. (1997).
4. H. Ishida, D.J. Allen, J. Polym. Sci., Part B: Polym. Phys. **34**, 1019 (1996).
5. H.D. Kim, H. Ishida, J. Appl. Polym. Sci. **79**, 1207 (2001).
6. J. Macko, H. Ishida, J. Polym. Sci., Part B: Polym. Phys. **38**, 2687 (2000).

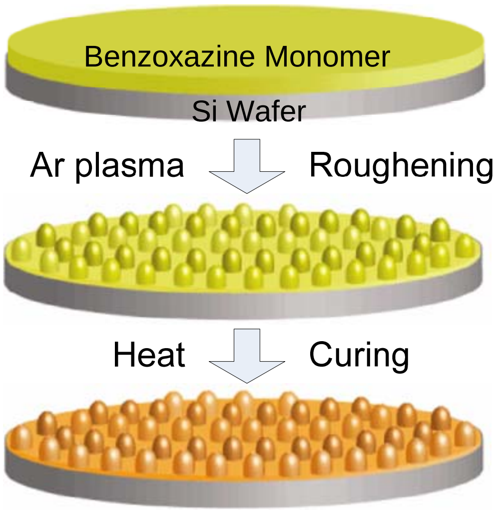

Fig.1 Procedure for forming antireflective benzoxazine films.

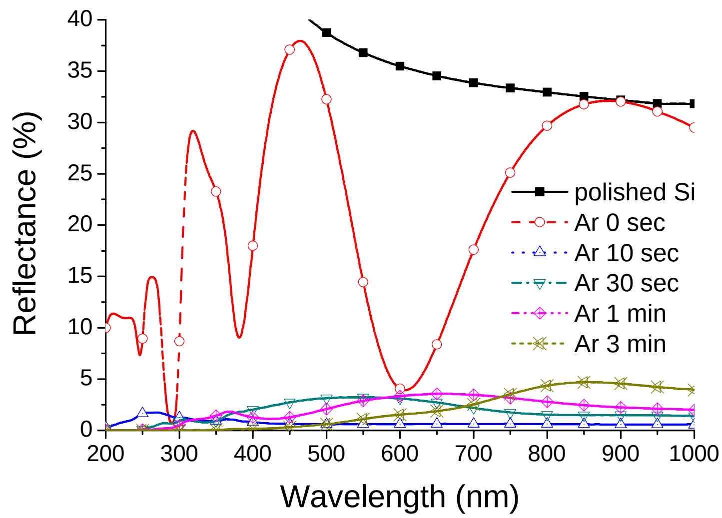

Fig. 2 Reflectance spectra of benzoxazine films with different Ar plasma treatment time.

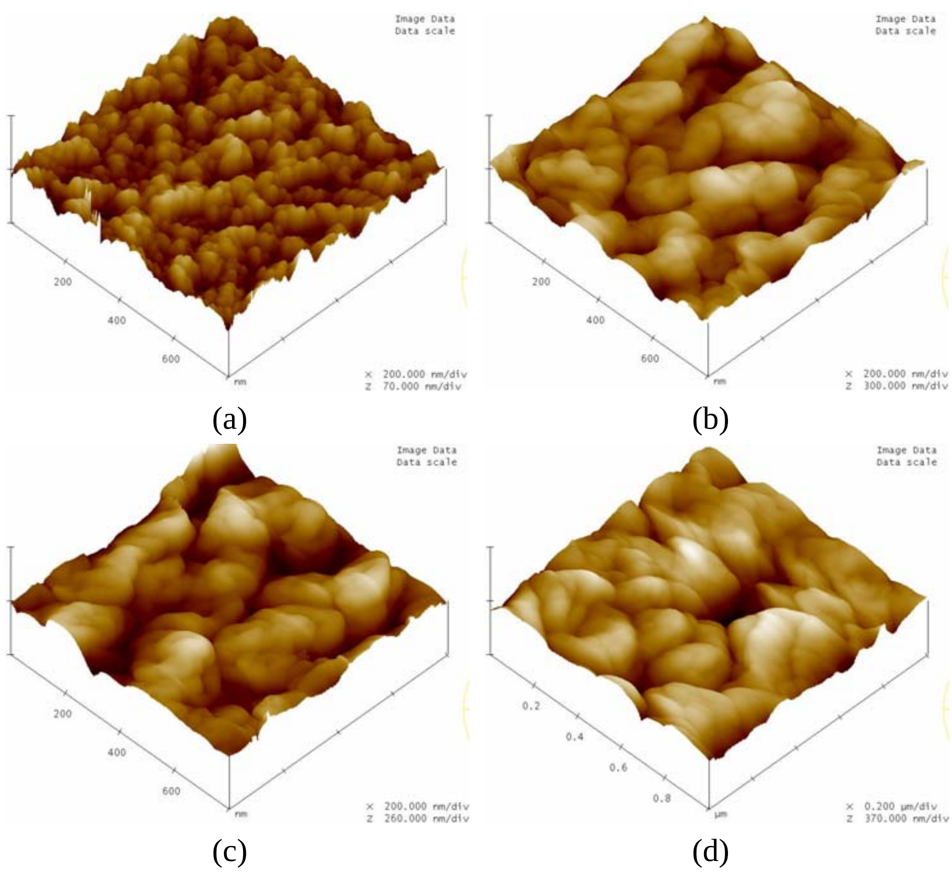

Fig. 3 AFM images of benzoxazine surfaces treated with Ar plasma for (a) 10 sec, (b) 30 sec, (c) 1 min, and (d) 3 min.