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ヘリウムプラズマ照射によるブラックシリコンの形成とその特性

Formation of Black Silicon by using Helium Plasma Exposure and Its Property

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The present study demonstrated a novel process to obtain nanostructure on Si surfaces for potential applications to optical devices [1]. The present technique employs no masks with a reduced number of processes favoring industrial applications. The surface morphology was suitable for incident photon trapping, which resulted in the efficient conversion of light energy to electric power by decreasing reflectivity as shown in Fig.1 (a) and (b) where scanning electron microscope analysis indicated a nanostructure of dense forest consisting of long cylindrical needle cones with a length of approximately 300 nm and a mutual distance of approximately 200 nm.

Raman spectroscopy and spectrophotometry supported the above expectations. The former shows a good crystallinity and no amorphous component on the surface. The process circumvents the use of mask and etching liquid, and involves soft ion bombardment of Si crystal because the incident He ions were of lower kinetic energy compared to that used in standard RIE (Reactive Ion Etching) for obtaining microscopic texture on Si surfaces to reduce reflectivity.

The present technology provides a crystallinity maintaining simple tool which was suggested by Raman spectroscopy and also supported by XRD measurement. The processed Si surface is not fragile but fairly firm to support a macroscopic electrode on it.

It is pointed out that the definitive ranges of substrate and plasma parameters like temperature, He ion flux and fluence, He ion incident energy required for nanostructure formation should be clarified in near future. The controllability of surface nanostructure may be obtained with those parameters in addition to He ion incident direction.

A strong tool to identify 2 D structure was suggested with a use of “form factor”. The nanostructure formation mechanism and the reason of the difference in nanostructure between Si and refractory metals should be studied although they are very challenging themes.

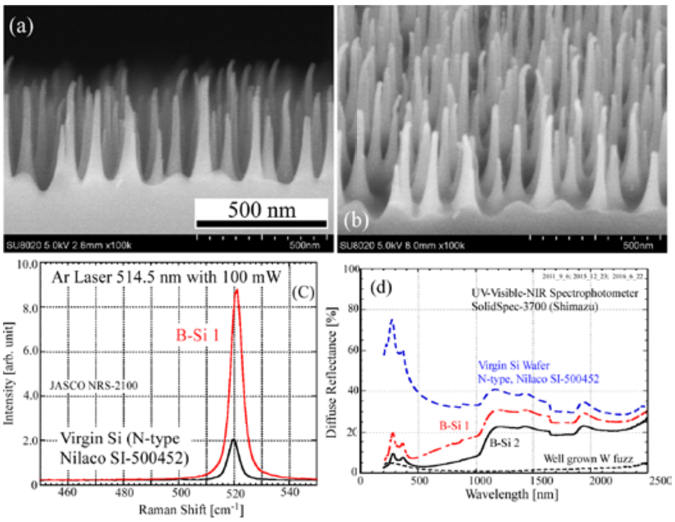

Fig.1 Surface morphologies after He plasma irradiation. He ion flux Γ_i = 1.4×10^{21} m^{-2}· s^{-1}, fluence F= 1.0×10^{25} m^{-2} and its incidence energy E_{He} = 40 eV at the substrate temperature of 500 ℃ (770 K). (a) FE-SEM cross-sectional view of the main surface area away from the fixing holes of N-type Si substrate (24×30×0.5 mm), (b) FE-SEM picture, with a tilting view angle of 30°, showing dense Si needles, (c) Raman spectra with incident laser wavelength of 514.5 nm for black Si (red line) and virgin Si substrate (black line), (d) shows diffuse light reflectance for B-Si 1 (red chain line), B-Si 2 (black solid line) and virgin Si wafer (dashed blue line) over the wavelengths between 200 and 2500 nm as measured using a spectrophotometer. B-Si 2 was obtained at double the He fluence for B-Si 1 and at the substrate temperature of 650℃. The reflectance data of well grown W fuzz is shown by a dashed black line as a reference, suggesting very close to black-body.

Reference

[1] S. Takamura, Y. Kikuchi et al., Jpn. J. Appl. Phys. Rapid Communications **55** (2016) 120301.