Formation of nanocrystalline silicon on insulator through aluminothermic reduction of silica-substrates

筑波大学 [1], 茨城工業高等専門学校 [2], ○ Muhammad Monirul Islam [1], 澤畠　淳二 [2], 秋本 克洋 [1], 櫻井 岳暁 [1]

Tsukuba Univ.[1], National Institute of Technology, Ibaraki College[2], ° Muhammad Monirul Islam[1], Junji Sawahata[2], Katsuhiro Akimoto[1], and Takeaki Sakurai[1]

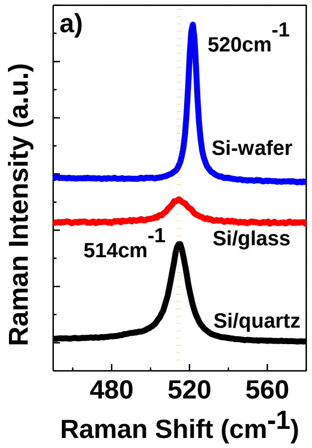
E-mail: islam.monir.ke@u.tsukuba.ac.jp

Introduction: Silicon (Si) is the most abundant semiconductor-material found in form of silica (SiO_2) contributing in the fields of macro to microelectronics. In particular, nanocrystalline Si (nc-Si) is promising for future optoelectronics, as it shows material properties of both amorphous-Si and polycrystalline-Si. Current methods of obtaining nc-Si involve re-crystallization of amorphous-Si, or direct deposition of nc-Si through chemical vapor deposition (CVD). Various complex-steps, requirement of high-temperature, toxic materials in the current techniques limit its potential applications. In this study, we have focused on a simple method for the formation nc-Si films on insulator-type substrates (i.e., silica: glass or quartz *etc*) through aluminothermic reduction of the substrates. According to thermodynamic properties of SiO_2, aluminothermic reduction occurs around melting point of aluminum (Al), (~ 650^{O} C) following the basic equations:

$$SiO_2\ (Solid) + 4e^- \rightarrow Si\ (reduced) + 2O^{2-} \qquad (1)$$
$$Al\ (s) \rightarrow Al^{+3} + 3e^- \qquad (2)$$
$$3SiO_2(S) + 4Al\ (S) = 3Si\ (s) + 2Al_2O_3(s) \qquad (3)$$

Experimental: Al thin-films with thickness of ~ 100 nm were deposited through thermal evaporation of Al on quartz or borosilicate glass-substrates. Then, Al/quartz (or glass) structure was transferred to a thermal annealing system, where it was annealed at 700^{O} C in the vacuum; thereby, going through aluminothermic reduction, where surface of the silica-substrate reduced to become Si-film. Si-films were characterized by Raman spectroscopy, photoluminescence, scanning electron microscopy (SEM), and optical measurement *etc*.

Results and Discussions:



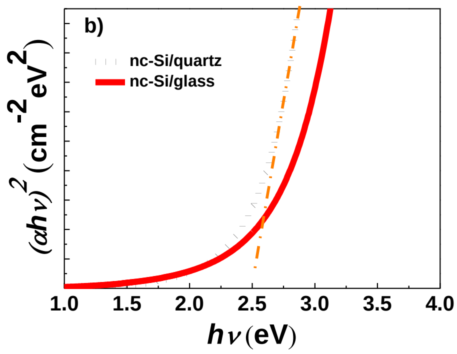


Fig.1 (a) Raman spectra of aluminothermic reduced Si-film on quartz-substrate; (b) Band-gap determination from data obtained by UV-visible measurement

Results and Discussions: Shown in Fig. 1(a) are the Raman spectra of Si thin-films obtained through aluminothermic reduction of a borosilicate glass and a quartz-substrates, performed at 700^{O} C with 1-hour of reaction time (annealing). Raman spectrum of the oriented single-crystal Si-wafer has been shown as a reference. A broadened asymmetric peak at ~514 cm^{-1} has been apparent for Si-films on both the glass and the quartz-substrate. A large shift of peak at 514 cm^{-1} comparing to the peak of Si-wafer at ~ 520 cm^{-1} roughly suggests formation of nc-Si through aluminothermic reduction of the surface of SiO_2-substrates. Optical band-gap (E_g), of the nc-Si films obtained by absorption measurement was found around 2.5 eV (Fig. 1 (b)), which is characteristic for the nc-Si thin-films. Annealing time was varied during reduction to study the effect of reaction time on the quality of the nc-Si films. Optical and structural properties were discussed in relation to the various annealing time.