Electrochemical reduction of diatom for the formation of silicon-film on silver-substrate

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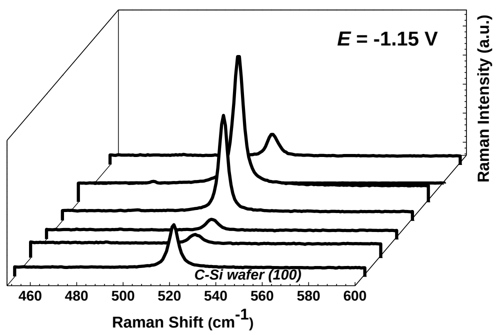
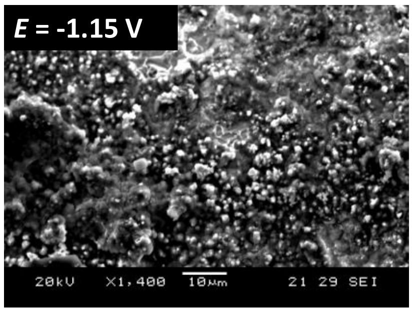
Most of the commercial solar cells are based on silicon (Si) which is most abundant solar energy material in form of silicates and silica (SiO_2). However, current production of Si using carbothermic reduction requires huge energy consumption and carbon-di-oxide emission. We aim to study formation of Si layer through reduction of SiO_2 using electrodeposition technique on low-cost substrate. According to thermodynamic properties of SiO_2, reduction occurs at high temperature of 850° C in $CaCl_2$ molten salts following the basic equation: SiO_2 (Solid) + $4e^-$ → Si (reduced) + $2O_2$. In this study, we have used diatomaceous earth, an alternative source for high purity Si. Diatomaceous earth is a siliceous sedimentary rock mainly consists of fossilized diatoms, a kind of alage. It is chemically composed of mainly SiO_2 ranging from 80-95 %, along with Al_2O_3, iron-oxide *etc.* We have used diatomaceous earth (SiO_2) with 99% purity obtained after a wet chemical purification process.

Experiments for the electrodeposition Si-film has been carried out in a Al_2O_3- crucible placed inside a quartz electrochemical cell equiped with three-electrode system. Graphite has been used as counter electrode (CE) as well as reference electrode (RE), while silver sheet (Ag) was used as the working electrode (WE) as well as substrate for the electrodeposition. Electrochemical analysis has been done under Ar-gas at 855^{O} Celsius using $CaCl_2$ molten salt. Chronoamperograms has been done at constant potential (E) applied between Ag-substrate (WE) and graphite reference electrode. Cyclic voltammetry (CV), and all the constant potential electrolysis were carried out with an HSV-110 potentiometer (Hokuto Denko, Japan).



(a)



(b)

Fig. 1 (a) Raman spectra on various spot of an electrodeposited Si-layer from diatom. Raman spectrum of an oriented crystalline Si (100) was also shown as reference. (b) SEM image of the surface of the Si-layer electrodeposited from diatomaceous earth (SiO_2) with the reduction potential of *E*= -1.15 V vs graphite-RE.

Shown in Fig. 1 (a) is the Raman spectra on various spots of an electrodeposited Si-layer on Ag-substrate deposited with potential, *E* = -1.15 Volt, applied between the Ag-substrate and Graphite-RE. relatively sharp and symmetric peak at ~ 519 cm^{-1} on some spots suggest formation of crystalline silicon on the Ag-substrate. However, various intensity of the main peak at various spots along with shift of the main peaks corresponds to single crystal Si-wafer indicates inhomogeneous crystalline composition associated with existence of micro-crystalline type mixed phases. X-ray diffraction (XRD) pattern also supports formation of multi-crystalline silicon. SEM image (Fig. 1 (b)) reveals that distribution of deposited-Si on the surface is mainly not homogeneous in nature. Clustering of small crystallites is evident with the grain size less than 1μm. Moreover, morphology of the formed Si-layer with just 1 hr of short deposition time exhibits rough surface. Effect of various applied reduction potential on the formation of Si layer through electrochemical reduction of SiO_2 has been discussed.

Ref: [1] Zulehner et al., Ullmann's Encyclopedia of Industrial Chemistry 5th ed., Vol. A23, 721–748 (VCH,Weinheim, 1995).