

Medium energy ion scattering and elastic recoil detection for solar silicon devices

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Significant enhancement of silicon-based devices reliability (lifetime) has been observed with the quality of the surface passivation. The standard thermal oxide growth involves processing at temperatures above 800°C, which can degrade crystalline Si properties, via defect and dopants migration, and segregation processes at the interface, lowering device lifetime. In order to overcome this obstacle, novel passivation was proposed that can be implemented at low temperatures.[1] In addition, some of the lifetime enhancements were contributed to hydrogen present at the SiO₂/Si interface.[2] The effect has been attributed to reduced hot-electron depassivation of hydrogenated and deuterated SiO₂/Si interfaces, where H or D passivates silicon dangling bonds. Possible mechanisms explaining this behaviour is the coupling of Si-H vibrational bending mode to bulk phonons in crystalline silicon.[3] It is undoubtedly a great advantage to be able to properly characterize not only bulk properties of Si devices but in addition, to provide determination of the precise character of any interfaces with high depth resolution and element sensitivity. Such insight into the bulk or surface properties can be related back to things like device performance or provide insight into why a particular material has the properties it does.

In this work we explore interface properties of crystalline Si heterojunction solar cells with plasma enhanced chemical vapour deposition (PECVD) grown silicon nitride layers with efficiencies approaching 17%.[1] The role of hydrogen at the interface was evaluated using elastic recoil detection (ERD), while interface profiling was done by medium energy ion scattering (MEIS) and Rutherford backscattering spectroscopy (RBS). Accurate quantification and profiling of hydrogen in thin-layer materials is challenging. The detection limit of traditional methods, such as secondary ion mass spectroscopy (SIMS) is about 10¹⁵ H/cm³, which is comparable with the density of dangling bond at the non-passivated SiO₂/Si interface (1×10¹³ cm⁻²) as measured by electron spin resonance. Here we use ERD as an alternative to SIMS for accurate quantification of hydrogen isotopes.

Medium energy ion scattering results indicate that distribution of Si, O and N are as expected from the deposition parameters. A simulation of MEIS spectra showed that the outermost layer was silicon oxinitride film with a thickness of 20 ± 2 Å. The position of the nitrogen peak indicates that most of nitrogen is confined within silicon nitride layer, however there is some interdiffusion of N into SiO₂ layer at the interface. Our results indicate that with increasing silicon nitride thickness there is a significant decrease in interfacial defect density and fixed charged densities (Figure 1).

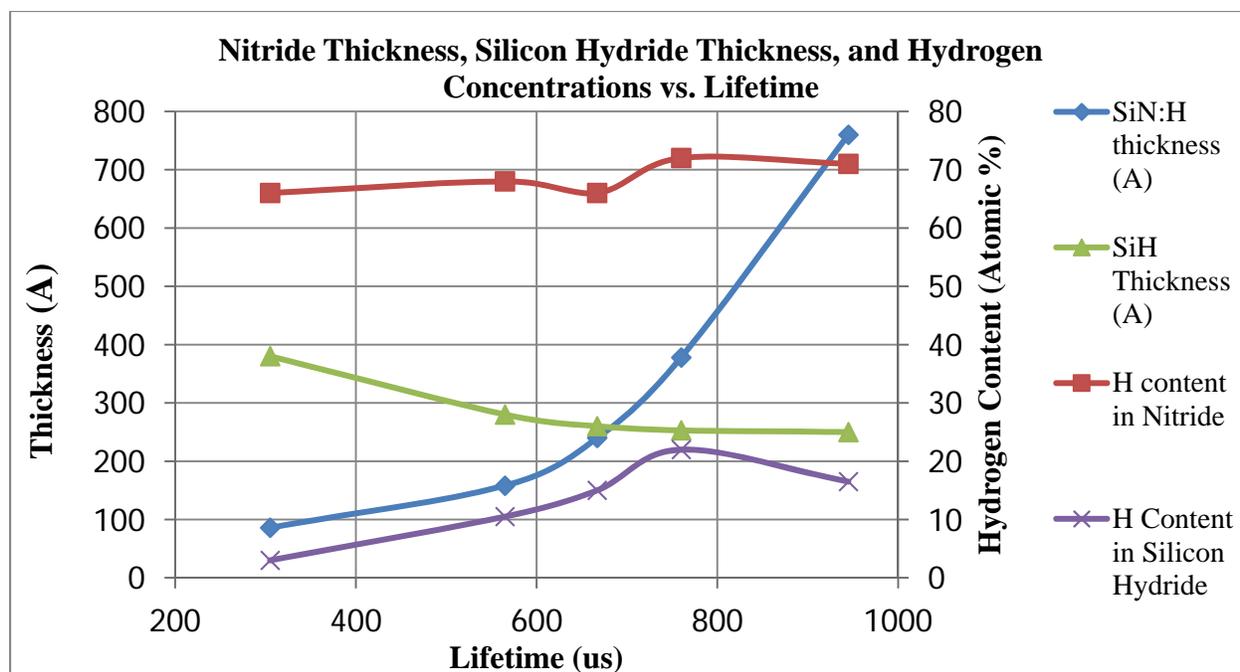


Figure 1: Silicon nitride thickness and hydrogen content variations with the observed lifetime of the solar cell devices.

There appears to be a correlation between an increased H content at the SiO₂/Si interface and higher observed minority carrier lifetimes. We argue that in the proposed passivation scheme, we achieve efficient termination of Si dangling bonds. There is no significant dissociation of Si-H bonds at temperatures below 600°C, while silicon nitride functions as a very good barrier for hydrogen diffusion. Further study of temperature related processes is needed to better understand the role such H content plays in the passivating native oxide-Si interfaces.

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