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ScienceDirect

Energy Procedia 92 (2016) 248 – 254

Energy Procedia

6th International Conference on Silicon Photovoltaics, SiliconPV 2016

Carrier lifetime in liquid-phase crystallized silicon on glass

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Abstract

Liquid-phase crystallized silicon on glass (LPCSG) presents a promising material to fabricate high quality silicon thin films, e.g. for solar cells and modules. Barrier layers and a doped amorphous silicon layer are deposited on the glass substrate followed by crystallization with a line focus laser beam. In this paper we introduce injection level dependent lifetime measurements generated by the quasi steady-state photoconductance decay method (QSSPC) to characterize LPCSG absorbers. This contactless method allows a determination of the LPCSG absorber quality already at an early stage of solar cell fabrication, and provides a monitoring of the absorber quality during the solar cell fabrication steps. We found minority carrier lifetimes higher than 200 ns in our layers (e.g. n-type absorber with N_D=2x10^{15}cm^{-3}) indicating a surface recombination velocity S_{BL}<3000 cm/s at the barrier layer/Si interface.

Keywords: multicrystalline silicon; thin film; laser crystallization; carrier lifetime; quasi steady-state photoconductance

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1. Introduction

Laboratory solar cells implementing liquid-phase crystallized silicon on glass (LPCSG) produced by line focus laser beam or electron beam (e-beam) crystallization of amorphous silicon (a-Si) layers on glass, showed open circuit voltages (V_{oc}) over 600 mV [1-5] making closer the gap of thin film crystalline silicon solar cells to multi-crystalline silicon wafer solar cells [6]. LPCSG presents a promising material to fabricate solar cells and modules, this technology could merge the advantages of crystalline silicon (c-Si) wafer technology with its high efficiency potential and thin film technology with low Si consumption and low cost monolithic integration for module

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doi:10.1016/j.egypro.2016.07.067

fabrication. LPCSG technology could be an approach to overcome the emerging limits for further cost reduction in standard wafer-based module technology as e.g. reduction of wafer thickness or increasing wafer size.

The introduction of barrier layers (BL) between the glass and the Si layer plays an important role in achieving a high electronic material quality after the crystallization process. The BLs must ensure good adhesion of Si (wettability), facilitating crystallization of high–quality Si, blocking diffusion of impurities from the glass, passivating Si interface defects and acting as a transparent antireflection coating for the superstrate configuration, furthermore it could serve as a dopant source for the absorber. Recent investigations were focused on combination of SiO_2, SiN_x, SiO_xN_y and SiC_x layers [7, 8] however, a combination fulfilling all the requirements is still objective of investigation.

Most developments of the LPCSG absorbers have been made by fabricating solar cells, measuring and analyzing current-voltage (IV) characteristics and quantum efficiency (QE) or on quasi-solar cells measuring the Suns-V_{oc} characteristic. In this paper, we introduce the measurement and analysis of injection level dependent lifetime (τ) measurements generated by the quasi steady-state photoconductance decay (QSSPC) method [9]. This contactless method provides information on the LPCSG absorber quality already at an early stage of solar cell fabrication, and a way to monitor the absorber quality during the solar cell fabrication steps.

In literature [1] the effective diffusion length (L_{eff}) of high-quality LPCSG absorbers is estimated from QE data to lie around 10-30 μm for solar cells with absorber thickness (W) in the range of W=5-10 μm and with efficiency in the range of 10%. Carrier lifetime can be calculated from the basic relation $\tau_{eff} = L_{eff}^2/D$ and diffusion constant $D=\mu_{eff*}kT/q$ where μ_{eff} is the effective carrier mobility. In Figure 1 this relation is shown for c-Si where μ, D and τ are calculated by using the "mobility calculator" on the pvlighthouse web page [10]. The relation of L_{eff} and τ_{eff} is shown for different n-type doping densities (N_D) and at an injection level (Δn) of 10^{15} cm^3. In addition, the relation is calculated for $N_D=2x10^{16}$ cm^{-3} for $\Delta n=10^{13}$ cm^{-3}, presenting no dependence on injection level for c-Si (in this range). Since the dependence of μ on doping concentration in LPCSG seems to be somewhat different to c-Si [1] the relation will be slightly different, nevertheless Figure 1 suggests that for $L_{eff} \approx 10$-30 μm [1] τ_{eff} of n-type LPCSG absorbers ($W \approx 5$-10μm) is in the range from a few ns to 1 μs.

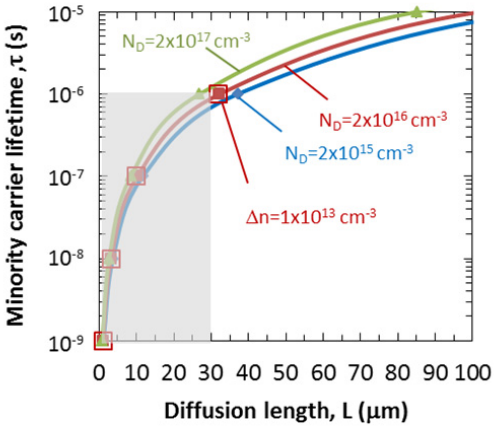

Fig. 1. From the lifetime-(ambipolar) diffusion length relation of c-Si (injection level $\Delta n=1x10^{15}$ cm^{-3}, red open squares: $\Delta n=1x10^{13}$ $cm^{-3}$for $N_D=2x10^{16}$ cm^{-3}), considering the lower mobility in LPCSG and the estimation of the $L_{eff} \approx 10$-30 μm [1] we estimate lifetimes for LPCSG absorbers to be in the range of a few ns to 1 μs (marked area in the figure).