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Investigation of charges carrier density in phosphorus and boron doped SiN_x:H layers for crystalline silicon solar cells

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Abstract

Dielectric layers are of major importance in crystalline silicon solar cells processing, especially as anti-reflection coatings and for surface passivation purposes. In this paper we investigate the fixed charge densities (Q_{fix}) and the effective lifetimes (τ_{eff}) of phosphorus

(P) and boron (B) doped silicon nitride layers deposited by plasma-enhanced chemical vapour deposition. P-doped layers exhibit a higher τ_{eff} than standard undoped layers. In contrast, B-doped layers exhibit lower τ_{eff}. A strong Q_{fix} decrease is to be seen when increasing the P content within the film. Based on numerical simulations we also demonstrate that the passivation obtained with P- and B-doped layers are limited by the interface states rather than by the fixed charges.

Highlights

► We investigate the properties of phosphorus and boron-doped silicon nitride films. ► Phosphorus-doped layers yield higher lifetimes than undoped ones. ► The fixed charges density decreases when increasing the films phosphorus content. ► Boron-doped films feature very low lifetimes. ► These doped layers are of particular interest for crystalline silicon solar cells.

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Introduction

Dielectric layers are of major importance in crystalline silicon solar cells processing, especially as anti-reflection coatings and for surface passivation purposes. So far the *p*-type silicon-based PV industry has mainly been relying on the hydrogenated silicon nitride (SiN_x:H), owing to its interesting anti-reflective properties and high passivation level on n^+ surfaces [1], [2], [3].

However, SiN_x:H performs rather poor in passivating p^+ surfaces. This is partly explained by the high density of positive charges contained in SiN_x:H films [1], [2]. Though Chen et al. [4] reported that for lightly doped p^+ emitters, SiN_x:H layers can reach the same passivation level as thermally grown SiO_2 layers, this is generally not the case [5]. Moreover, when used for *p*-type silicon solar cells rear-side passivation, SiN_x:H induces parasitic shunting, hence limiting the cells efficiency [6].

For these reasons other dielectrics or dielectrics stacks have been proposed for p^+ surfaces passivation. Excellent passivation levels have for instance been obtained using aluminium

oxide [7], [8]. In the field of rear-side passivation of *p*-type silicon solar cells, and especially for PERL-like solar cells, efficiencies above 19% have been reported using Al_2O_3/SiN_x:H or SiO_2/SiN_x:H stacks [9].

In the last few years there has also been a growing interest for alternative dielectric layers, such as phosphorus (P) and boron (B) doped dielectric layers. It has indeed been found that P-doped silicon carbide alloys, such as SiC(P) [10] and SiCN(P) [11], provide excellent passivation on both *n*- and *p*-type surfaces. Surface passivation with B-doped dielectrics is still subject to discussion, though high passivation levels have been recorded with SiC(B), especially on p^+ emitter [5], [12].

Another interesting feature of doped dielectrics is that they can be used as tunable dopants sources. Blanket diffusion from SiCN(P) has already been demonstrated [13], while laser doping from SiC(P), known as the "PassDop" layer, is widely used for high-efficiency *n*-type silicon solar cells processing [14].

Moreover, if the added amount of P or B is small, the optical properties of the resulting films are not changed in a large extend [15]. Doped dielectrics can hence be used as AR coatings without major modifications, especially concerning the thickness to be deposited.

Nevertheless most of the studies so far focused on doped silicon carbide compounds, and very few investigated the properties of doped SiN_x:H layers [16]. This work thus aims at studying the properties of P- or B-doped SiN_x:H layers deposited by plasma-enhanced chemical vapour deposition (PECVD). We focus on the respective influence of the field-effect and the interface states passivation through the measurements of fixed charge densities and effective lifetimes.

Section snippets

Experimental

n- and *p*-type, 1–5 Ωcm, 280 μm thick, float-zone (FZ) silicon substrates were used for this study. The *n*-type substrates are both sides mirror polished, while the *p*-type substrates were chemically polished using a 1:3:3 $HF:HNO_3:CH_3COOH$ solution.

The doped SiN_x:H layers were then deposited using a Plasma-Therm Quadra D200A direct PECVD reactor. This system operates at 13.56 MHz. All layers were deposited at 300 °C. The precursor gases were silane (SiH_4) and ammonia (NH_3), with a ratio $R=NH_3/SiH_4=3$…

Phosphorus-doped SiN_x:H

The variation of Q_{fix} with the PH_3 flow is plotted in Fig. 2. A positive charge of $9.3\times10^{12}\,cm^{-2}$ is obtained for the as-deposited standard SiN_x:H layer without PH_3. This value is consistent with other data on similar layers [1], [2], [26], though a little bit higher.

For as-deposited SiN(P) layers, an important decrease of Q_{fix} is to be seen when adding PH_3. Q_{fix} indeed drops from $9.3\times10^{12}\,cm^{-2}$ to $2.3\times10^{12}\,cm^{-2}$ when going from 0 sccm (standard SiN_x:H layer, no PH_3 added) to 10 sccm of PH_3. In…

Boron-doped SiN_x:H

The variation of τ_{eff} with the TMB flow for both as-deposited and fired SiN(B) layers is presented in Fig. 8. In both cases a steady decrease of τ_{eff} is to be seen when increasing the TMB flow. Lifetimes below 10 μs are measured for high TMB flows, which is very low considering that we used FZ substrates. Such low lifetimes suggest a very defective interface between the silicon substrate and the SiN(B) layers.

Fig. 9 gives the variation of Q_{fix} with the TMB flow. It is to be noticed that no…

Conclusion

In this paper we investigated the fixed charge density and the effective lifetime of phosphorus and boron-doped silicon nitride layers, deposited by plasma-enhanced chemical vapour deposition.

A strong Q_{fix} decrease with the PH_3 flow is to be seen for SiN(P) layers. The best as-deposited passivation is obtained for a PH_3 flow of 25 sccm, for which τ_{eff} equals 1.2 ms, a value three times higher than for the standard undoped nitride. Moreover this passivation is found to be stable under IR firing,…

Acknowledgements

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References (34)

F.W. Sexton
Solar Energy Materials (1982)

A. Cuevas
Solar Energy Materials and Solar Cells (1999)

J. Maserjian *et al.*
Solid-State Electronics (1974)

S. Gall *et al.*
Energy Procedia (2012)

R. Hezel *et al.*
Journal of Applied Physics (1981)

R. Hezel *et al.*
Journal of the Electrochemical Society (1989)

F.W. Chen *et al.*
Applied Physics Letters (2006)

R. Petres *et al.*

S. Dauwe *et al.*
Progress in Photovoltaics: Research and Applications (2002)

B. Hoex *et al.*
Applied Physics Letters (2007)

P. Saint-Cast *et al.*
Applied Physics Letters (2009)

T. Dullweber *et al.*
Progress in Photovoltaics: Research and Applications (2012)

S. Janz *et al.*
Applied Physics Letters (2006)

R. Ferre *et al.*
Progress in Photovoltaics: Research and Applications (2008)

J. Seiffe *et al.*

R. Ferre *et al.*
Applied Physics Letters (2011)

D. Suwito *et al.*
IEEE Transactions on Electron Devices (2010)
There are more references available in the full text version of this article.

Cited by (10)

Blue-violet emission of silicon carbonitride thin films prepared by sputtering and annealing treatment

2021, Applied Surface Science

> *Citation Excerpt :*
> …The photoelectric property of SiCN films did also attracted substantial research interests due to the wide adjustable bandgap from 2.86 eV to 5.0 eV [4,5]. Hence, the SiCN thin film is regarded as a promising candidate for the development of solar cells, blue or violet optoelectronic devices, full-color displays, and high-density optical memories due to the adjustable bandgap and luminescent property [5–8]. SiCN films, as a ternary compound material, show a complex and uncertain microscopic structure, including various cluster forms, multiple phase structures, and bonding types.…

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The influence of nitrogen on laser doping from phosphorous doped a-SiNx layers

2016, Solar Energy Materials and Solar Cells

> *Citation Excerpt :*
> …The concept of using passivation layers as dopant sources for laser doping was since investigated by various groups. Laser doping from SiNx:P and SiNx:B was demonstrated by Paviet-Salomon et al. as well as Hameiri et al. for the application as emitter passivation/selective emitters formation or rear side passivation/LBSF formation [14,22,23]. Steinhauser et al. presented a similar approach called fPassDop based on SiNx:P for the application as a rear side passivation of n-type silicon solar cells [24].…

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Light-induced enhancement of the minority carrier lifetime in boron-doped Czochralski silicon passivated by doped silicon nitride

2015, Applied Surface Science

> *Citation Excerpt :*
>
> …This implied that the dopant, phosphorus, in P-doped SiNx, got into the silicon substrate after deposition, resulting in the change of the conduction type of the Si substrate. A similar phenomenon was reported by Paviet-Salomo et al. that phosphorus was doped into Si substrate after the deposition of P-doped SiNx [23]. In order to prove that P ions have been doped into the silicon, the doping concentration measurement was conducted on the post-deposited Si wafer by an Electrochemical Capacitance Voltage (ECV) tester (CVP21, Germany Buchanan), and the elemental analysis on the Si surface was carried out by Secondary Ion Mass Spectrometry (TOF-SIMS, 2100 Trift II).…

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Firing-stable PassDop passivation for screen printed n-type PERL solar cells based on a-SiN<inf>x</inf>:P

2014, Solar Energy Materials and Solar Cells

> *Citation Excerpt :*
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> …While the formation of an inversion layer results in parasitic shunting on p-type silicon solar cells [6], a-SiNx is suitable for n-type rear side passivation due to the formation of an accumulation layer. Silicon nitride can be doped by both phosphorous and boron and has thus been used to form selective emitters [7–9]. Our approach combines all these techniques to provide a firing-stable PassDop (fPassDop) layer stack based on amorphous, phosphorous doped silicon nitride (a-SiNx:P).…

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2022, IEEE Journal of Photovoltaics

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