STUDY OF SPUTTERED PASSIVATION LAYERS PROPERTIES BY MEANS OF MW-PCD MEASUREMENT

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ABSTRACT

In this work is described measurement method for determination of minority carrier lifetime, which is one of recombination parameters. For determination of minority carrier lifetime well known microwave-detected photoconductance decay (MW-PCD) method was used. The layers of SiN_x were sputtered by means of RF magnetron. The aim of work was evaluation of both front and back side surface recombinations and optical properties of sputtered layers and their comparison with passivatinon layers on standard solar cells made by Solartec company (Czech Republic).

1 INTRODUCTION

Measurement of the recombination properties is mostly important for diagnostic of silicon solar cells. The efficiency of a crystalline silicon solar cell is strongly determined by the bulk carrier recombination lifetime τ_{eff}, the emitter saturation current density J_{0E} and the effective surface recombination velocity (SRV) $S_{eff.back}$ at the rear of the cell. For lifetime minority carrier measurement we used the microwave-detected photoconductance decay (MW-PCD) method.

In standard solar cells industry has been using the passivation layer on the both sides of silicon substrates. For deposition of SiN_x passivation films the reactive magnetron sputtering was used in this work. The main advantage of reactive magnetron sputtering is low process temperature – using low-temperature amount of the crystal lattice defects decrease. Next reason for this technology implementation is purity of process and relatively high deposition rate. The most important material for silicon solar cells surface passivation is at present time the silicon nitride. The quality of deposited SiN_x on the front side of solar cell is important for determined of antireflection layer properties.

The passivation layer on the back side eliminates the crystal-lattice defects thereby increasing minority carrier lifetime. By covering of back side of the cell recombination effects in the silicon bulk and silicon surface are reduced.

2 SIN$_X$ LAYER PROPERTIES

The SiN$_x$ layers were deposited by means of RF reactive magnetron sputtering in an industrial LEYBOLD-HERAEUS Z550 sputtering device with 150 mm silicon cathode. All films were deposited in the RF mode. The substrates were preheated to 50°C. The RF power for magnetron sputtering was from 400 W up to 600 W, deposition rate were from 2 nm/min up to 5 nm/min., depending on the process parameters. The gas mixture (Ar-N$_2$) was control in steady pressure condition by mass-flow controllers. In presented SiN$_x$ deposition runs hydrogen was not used in the gas mixture.

The deposition rates were evaluated from the film thickness using a Talystep profilometers. On the front side of silicon substrates was deposited SiN$_x$ of 105 nm ± 5% in case monocrystalline and 95 nm ± 5% for multicrystalline substrates.

3 RECOMBINATION PARAMETERS MEASUREMENT

3.1 MW-PCD MEASUREMENT PRINCIPLE

In the MW-PCD (Microwave Photoconductance Decay) method, within the wafer under test a short laser pulse (duration 100 ns) generates excess carriers. After termination of the laser pulse, the excess carriers recombine in the bulk and at the surfaces of the wafer. The decay of the excess carrier concentration within the wafer is measured via the reflected microwave power. As the microwaves penetrate deep into the wafer, the recorded signal represents a spattialy averaged excess carrier concentration. The asymptotic part of the resulting transient curve is fitted with an exponential decay function, where the time constant of the exponential function is the effective carrier lifetime τ_{eff} of the wafer under test. The maximum intensity of the bias light is ~ 250 mW/cm^2 using an additional halogen lamp.

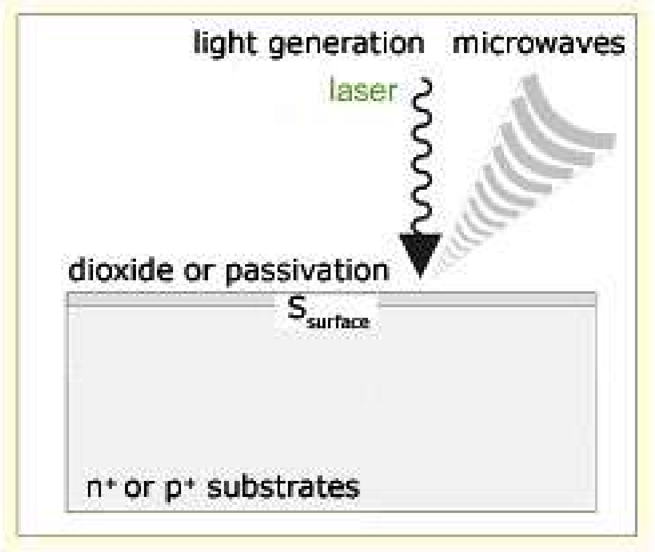

Fig. 1: Principle of MW-PCD measurement.

Hence, MW-PCD system is limited to $\Delta n \leq 2\times10^{15}$ cm^{-3}, depending on the lifetime of the measured material. Standard MW-PCD method gives no information about the excess carrier density at a particular bias light intensity. The bulk injection level is given from the measured bias light intensity and the measured effective lifetime using the semiconductor simulation program. The bias light illuminates a relatively large section of the sample and the laser beam has a small diameter (a few mm) and hence the measured quantity is a local carrier lifetime (Fig. 1).

MW-PCD measurement is non-contact method where minority carrier lifetime can be measured within bulk substrates or its surface. For measurement of carrier lifetime on the silicon surface the iodine-ethanol solution can be used. Iodine-ethanol is here an ideal passivation substance for silicon surface. In principle, before measurement the silicon substrate is inserting inside of iodine-ethanol solution for elimination of surface recombination effect. Hence, the minority carrier lifetime measurement gives the values of lifetime within bulk only. The substrate is measured without passivation. Immediately after this passivation step of silicon surface the substrate is measured again. Now, the lifetime value contains data of all substrate (surface and bulk). After comparison we can determine quality of surface passivation on the silicon substrates.

3.2 MW-PCD MEASUREMENT

On the Fig. 2 and Fig. 3, there is a comparison between multi and mono-crystalline silicon substrates by means of MW-PCD measurement. In case of multi-crystalline substrate the grain size within the poly-substrate is critical parameter for quality of passivation layers. The top value of minority carrier lifetime is 12,2 µs for non-passivated substrate and 12,4 for substrate with sputtered passivation layer of SiN_x. The quality of silicon material is very important in case of the mono-crystalline substrate. The purity of silicon determine the lifetime on the silicon surface and within bulk. The top value of lifetime is 13,3 µs for non-passivated substrate and 10,2 µs for substrate with sputtered passivation layer of SiN_x.

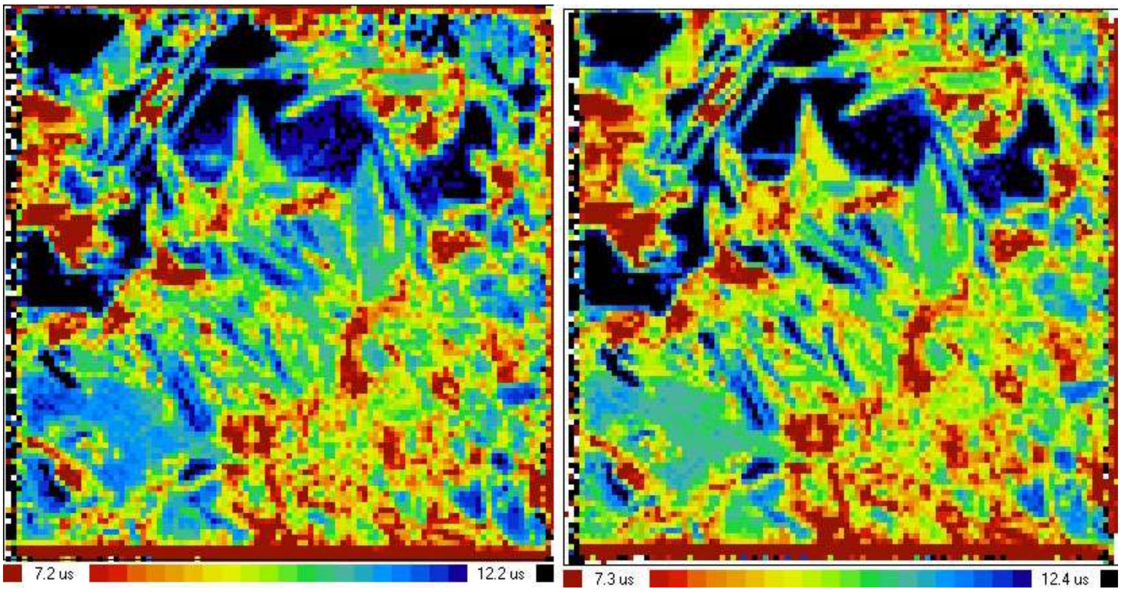

Fig. 2: Measurement of m-crystalline silicon substrates; before passivation (on left) and next to sputtered of SiN_x (on right).

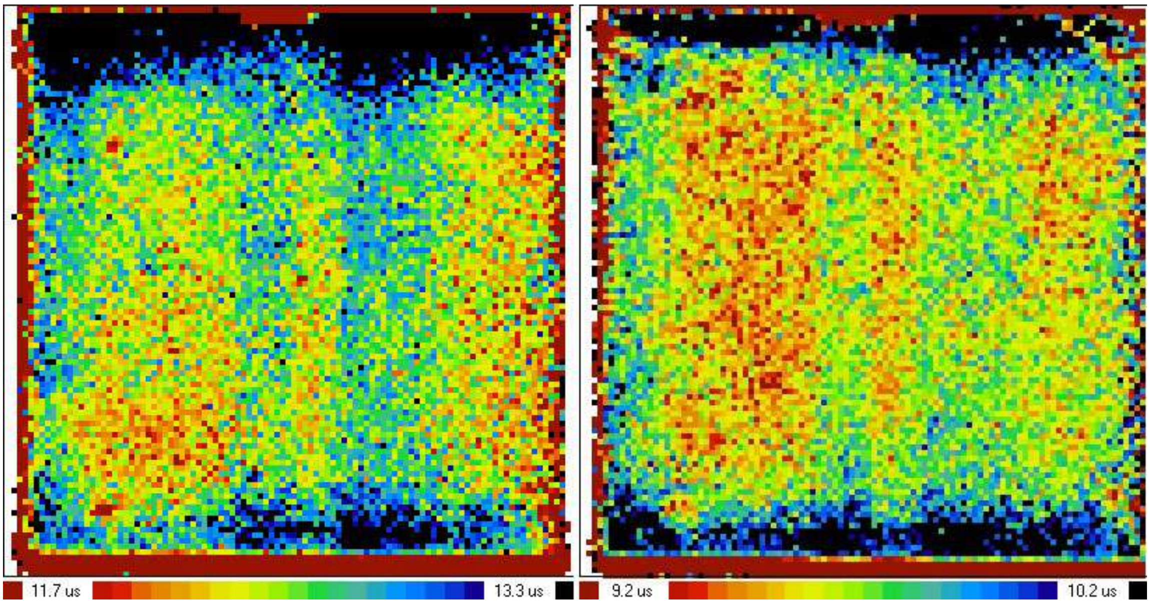

Fig. 3: Measurement of mono-crystalline silicon substrates; before passivation (on left) and next to sputtered of SiN_x (on right).

4 DISCUSION AND CONCLUSION

In our work SiN_x passivation layers were deposited on the multicrystalline and monocrystalline silicon substrates. The layers were created by means of RF reactive magnetron sputtering with its thickness of 105 nm (monocrystalline) and 95 nm (multicrystalline).

For determining of minority carrier lifetime well known microwave-detected photoconductance decay (MW-PCD) method was used. By the help of this technique we measured monocrystalline and multicrystalline substrates before passivation layer deposition and after sputtered of SiN_x passivation layer. The passivation effect by monocrystalline substrates is decreased. The reason here can be strongly n^+ dopped diffusion layer with large deffect concentration..

After SiN_x layer deposition on multicrystalline substrate the minority carrier lifetime was increased. The top value of minority carrier lifetime is 12,4 µs. The quality of passivation layer is strongly dependent on the grain size within poly-silicon substrate.

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