JOURNAL OF NANO- AND ELECTRONIC PHYSICS
Vol. 7 No 1, 01036(3pp) (2015)
ЖУРНАЛ НАНО- ТА ЕЛЕКТРОННОЇ ФІЗИКИ
Том 7 № 1, 01036(3cc) (2015)

The Features of Decay Kinetics of Photovoltage in Silicon Crystals Used in Solar Energy Caused by a Weak Stationary Magnetic Field

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(Received 12 September 2014; revised manuscript received 17 February 2015; published online 25 March 2015)

The influence of a weak stationary magnetic field on the decay kinetics of photovoltage in solar-Si crystals is studied. The features in the behavior of electrophysical parameters showed that the stability of the short-term and long-term components of photovoltage depends on the duration of magnetic treatment. Short time of magnetic treatment leads to increase, and long magnetic treatment causes reduction of both components of photovoltage in comparison with control crystals. It is revealed that character of magneto-stimulated change of photovoltage kinetics correlates with a charge condition of surface.

Keywords: Solar-Si, Carrier lifetime, Magnetic field, Charged impurities.

PACS numbers: 68.35.bg, 61.43.Dq, 61.72.Hh, 73.40.Qv

1. INTRODUCTION

An idea associated with the possibility to influence the physical properties of semiconductors by different treatments has always attracted attention. A scientific search performed in recent years allowed us to reveal the change in the micromechanical and electrophysical properties of silicon crystals used for microelectronics needs after their treatment in a weak stationary magnetic field [1-4]. Study of the changes (conditioned by magnetic treatment) in the physical properties in solar silicon (solar-Si) crystals used in solar engineering are almost absent in the scientific literature today. At the same time, this information is rather important, especially, if we are talking about the change in carrier lifetime. The latter is of great practical importance, since it is aimed at modernization of production of solar elements operating in a number of cases in the extreme conditions of external influences.

The aim of the present work was to establish the dependence between the magnetic influence and decay kinetics of the photovoltage in solar-Si crystals.

Determination and study of such dependence is of interest for both the clarification of the mechanisms of impact of magnetic fields on the solid-state objects and the solution of the practical forecasting problems of the solar cell behavior, for the production of which solar-Si crystals are the master slices.

2. INVESTIGATION TECHNIQUE

Solar-Si (s-Si) crystals used in the work were doped with boron to the specific resistance of 5 Ohm·cm and had {100} crystallographic orientation. Magnetic treatment (MT) consisted in exposure of the studied samples in a weak stationary magnetic field with the induction of $B = 0.17$ T during $t_{MO} = 2$ days, $t_{MO} = 14$ days and $t_{MO} = 200$ days. Two decay components – short-term (τ_1) and long-term (τ_2) – were determined by the kinetic dependences of the photovoltage decay. These components were defined before MT starting, immediately after MT completion and also long after completion of MT. Photovoltage decay was measured by the condenser method [5]. Laser photodiode with the wavelength of 650 nm was used to excite the photovoltage in s-Si crystals. At that, duration of pulses applied from generator and exciting the photovoltage was equal to $t = 14$ μs.

3. RESULTS AND DISCUSSION

Experimental results associated with the influence of a magnetic field on the short-term (τ_1) and long-term (τ_2) components of the photovoltage decay, represented in Fig. 1a, b, indicate the following. Effect on the s-Si crystals by a short MT ($t_{MO} = 2$ days) led to the increase in both components compared with the values inherent to the initial s-Si crystals, i.e. crystals which did not undergo MT.

The effect of decrease of both components up to the values significantly lower compared with control crystals is observed with increasing MT duration to 14 days and 200 days.

It is not improbable that the obtained results of non-monotonic change in the electrophysical parameters can be consistently explained based on the ideas developed in [6, 7]. As it is noted in [6], effect of a pulsed magnetic field on the metal/dielectric/semiconductor (MDS) structure is accompanied by the breakage of chemical bonds and leads to the generation of surface states (SS) and a negative charge in the oxide (dielectric).

Thus, the authors of [6] in the description of the observed magnetosensitive effects take into account both the magneto-stimulated restructuring processes and the processes associated with the change in the surface charge state during MT. It should be noted another aspect of magnetic influence: magnetic field activates the silicon surface and amplifies the adsorption and gettering processes [7]. Since in our study we deal with «s-Si + SiO_2» system (where SiO_2 is a natural oxide always existing on the silicon surface), then, following [6, 7], one can assume the next interpretation of the established laws.

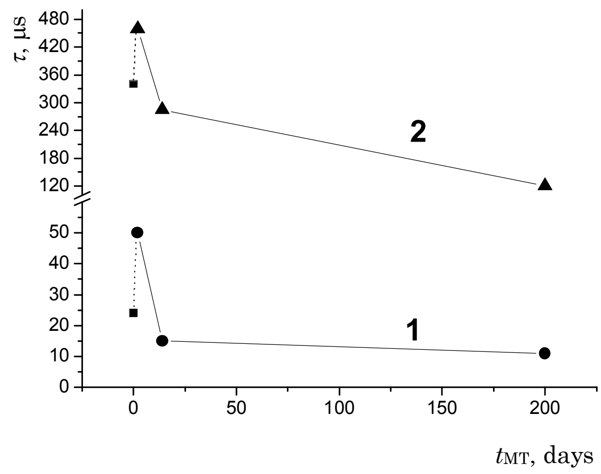

Fig. 1 – Dependence of the short-term (1) and long-term (2) components of the photovoltage decay in s-Si crystals on the duration of MT: $B = 0.17$ T. ■ – values of τ for control samples, which did not undergo MT

For a small MT duration ($t_{MO} = 2$ days), the charge formed on the surface and in the near-surface region due to the adsorption of charged impurities from the ambient atmosphere and on account of the gettering by the surface of charged impurities from the silicon bulk, is much smaller in magnitude than the charge formed on the surface during long MT ($t_{MO} = 200$ days). Presence of a small amount of charged impurities in the first case and its significant increase in the second case explain the difference in the behavior of the parameters τ_1 and τ_2 at short and long MT duration. One might assume that in the first case at a small MT duration, the charge formed as a result of MT neutralizes sparse charged impurities which are present on the surface that leads to the increase in the parameters τ_1 and τ_2. In the second case (at a long MT duration), the value of the negative charge generated on the s-Si-SiO_2 interface boundary is inefficient for the total neutralization of a large quantity of charged impurities appeared on the magneto-activated surface because of the adsorption and gettering processes. Probably, at a long MT duration, the adsorption processes, on the one hand, neutralize charged centers on the surface, and, on the other hand, increase its charge state forming additional donor and acceptor levels on account of proadsorbed particles. The latter leads to the fact that both the short-term and the long-term components of the photovoltage decay at long MT sharply decrease. At that, decrease occurs till the values substantially lower than in control crystals that indicates higher charge state of the magneto-activated surface compared with the charge state of the surface in control (initial) s-Si crystals. The investigations (we have performed) of the change in the surface electric potential as a result of magnetic action confirm the increase in the surface charge during long MT [8, 9].

The studies carried out in the present work allowed to follow the stability of the charge formed at different MT durations. At a short MT duration ($t_{MO} = 2$ days) (see Fig. 2a), the values of the parameters τ_1 and τ_2 sharply decrease during the first 20 days after MT completion.

Henceforth, decrease in the parameters continues, although relaxation rate slows down slightly. In contrast to this case, at a long MT ($t_{MO} = 200$ days) (Fig. 2b), relaxation of the parameters τ_1 and τ_2 during 20 days is almost absent. In 230 days after completion of MT, a slight decrease in the parameter τ_1 takes place, at that parameter τ_2 is not almost changed.

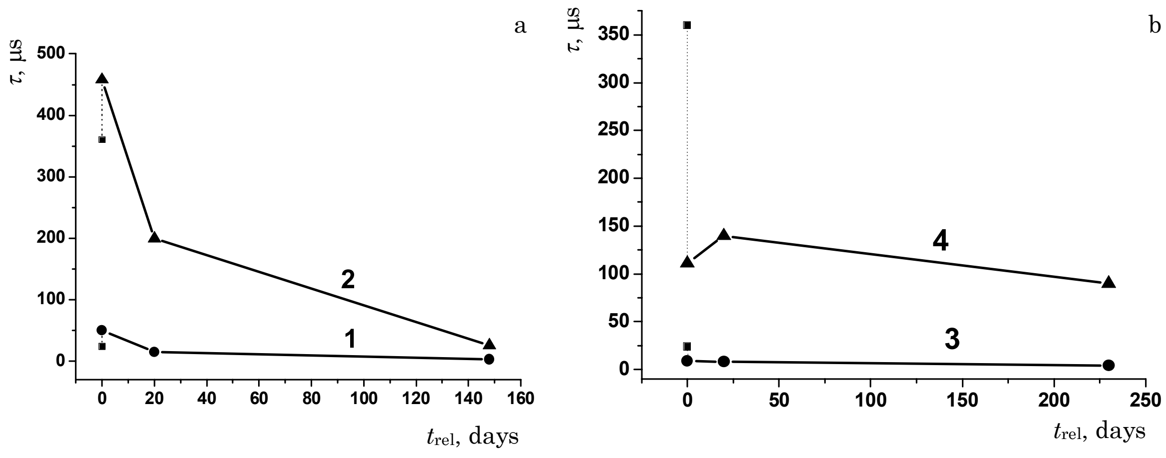

Fig. 2 – Dependence of the short-term (1, 3) and long-term (2, 4) components of the photovoltage decay in s-Si crystals on the time after MT completion. $B = 0.17$ T; $t_{MO} = 2$ days (a), $t_{MO} = 200$ days (b). ■ – values of τ for control samples, which did not undergo MT

The above stated experimental facts indicate the influence of MT duration on the stability of the surface charge state of s-Si crystals. At the short-term MT, the charge state is unstable and sharply decreases after MT completion. At the long-term MT, the charge state formed on the s-Si surface maintains stability for a long period of time.

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