Features of FeB pair light-induced dissociation and repair in silicon n^+–p-p^+ structures under ultrasound loading

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The influence of ultrasound on iron–boron pair dissociation and association in silicon n^+–p-p^+ structures were investigated experimentally. The FeB pair transformations were monitored by measurements of short circuit current kinetics. It was found that ultrasound causes the decrease in both the concentration of pairs, which were dissociated by light, and time of association. The phenomenon was investigated at different light intensities, temperatures, frequencies and power of ultrasound loading. The possible mechanisms underlying the revealed effects were analysed.

I. INTRODUCTION

It is of wide knowledge that the properties of semiconducting crystals and structures are determined very much by their impurity compositions. As a result, the methods aimed at modifying the system of defects are very important for practical applications. Most of the similar methods use irradiation, thermal treatment or specific conditions of crystal growth. However, numerous experiments show that ultrasound also represents a sufficiently effective instrument in order to better control the semiconductor defects. For example, it has been found that the acoustic waves cause spatial redistribution of defects[1–6], transformation of metastable point defects[7–9], recharging of recombination centers[10,11], low temperature annealing of radiation defects[12–16]. The effects of this kind are observed in particular in silicon, which is the basic modern material used in microelectronics and solar power engineering[1,2,5,8,12,15,17,18].

The usage of active ultrasound (US) has its advantages due to local action of elastic oscillations and the possibility to adjust the external impact by changing the type, polarization or frequency of acoustic waves[19]. However, this method of modifying the defect system has not found wide application not least because of the lack of appropriate experimental research. In our opinion, it is most promising to use US loading (USL) as an additional factor of influence during various technological processes, which causes, in particular, the transformations in the defect system. This assumption is supported by the results obtained during ion implantation performed in the US field[1,17,20].

Iron is an important impurity in silicon–based integrated circuit and solar cell technology[21]. Most often, iron-related defects are the main recombination centers that determine the lifetime of minority charge carriers in particular and device characteristics in general. Therefore the methods aimed at iron gettering at various stocks have practical importance. In the publications, there is rather much information about this kind of defects. It is known that in thermal equilibrium at room temperature virtually all Fe_i is present as Fe_iB_s pairs in Si:B[22,23]. FeB pair dissociation can be accomplished by illumination at room temperature, by minority carrier injection, or by increasing the temperature[22,24,25]. Moreover, ultrasound vibrations with the frequency of $25-80$ kHz and acoustic lattice deformation amplitude of $10^{-6}-10^{-5}$ have been found to be capable of destroying FeB pairs[26,27]. In practice, however, the most widely used technique is light-induced dissociation. The peculiarities of the dissociation and subsequent repair are well studied[22–24,28–33]. However, to the best of our knowledge, there are no reports about US impact on these processes.

Our aim is to study experimentally the influence of ultrasound loading with the frequency of $2-30$ MHz and lattice deformation $< 2\cdot10^{-6}$ on the processes of FeB $\leftrightarrow$ Fe_iB_s transformations in silicon solar cells (SCs). The prethreshold intensity is used with the aim to prevent irreversible changes of the material properties. The obtained results can be used for subtle acoustically controlled tuning of the processes involved in iron atom gettering.

II. EXPERIMENTAL AND CALCULATION DETAILS

The n^+-p-p^+-Si samples used in the experiment are shown in Fig. 1. The structure was fabricated from a 380 μm thick p-type boron doped Czochralski silicon wafer with [100] orientation and resistivity of 10 Ohm·cm. The n^+ emitter with surface resistance of about $20-30$ $\Omega/\Box$ and thickness of 0.7 μm was formed by phosphorus diffusion at 940°C. The anti-recombination isotype barrier was created by using p^+ layer ($10-20$ $\Omega/\Box$, 0.6 μm) formed by boron diffusion at 985°C. The antireflective and passivating SiO_2 (40 nm) and Si_3N_4 (30 nm) layers were formed on the front surface as well. The solid and grid Al contacts were formed on the rear and front surfaces respectively. The samples used in the experiment had an area of 1.52×1.535 cm^2.

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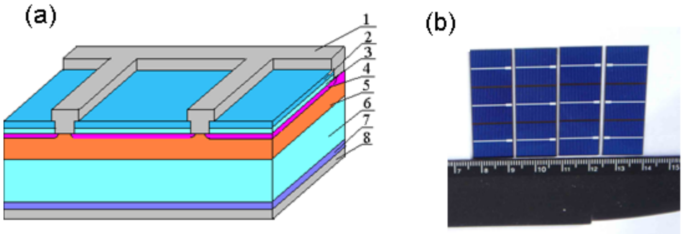

FIG. 1. (a) Scheme of the sample. 1 —- frontal Al electrode; 2 —- Si_3N_4; 3 —- SiO_2; 4 —- induced n^{++}-layer; 5 —- diffusion n^+-layer; 6 —- p-base region; 7 —- diffusion p^+-layer; 8 —- rear Al electrode. (b) View of real solar cells; the photo was taken from the side of frontal metal electrode.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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