GIANT LATERAL PHOTOVOLTAIC EFFECT IN THE TiO_2/SiO_2/p-Si HETEROSTRUCTURE

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Motivation

The lateral photovoltaic effect (LPE) occurs when a laser beam nonuniformly irradiates the surface of a pn-junction or a heterojunction, and a large number of electron-hole pairs are excited and then separated by this pn junction in the illuminated region by means of a built-in field [1, 2]. Interest to this effect is due to the linear dependence of the lateral photovoltage on the laser spot position between the electrodes, which can be used, for example, in position-sensitive detectors (PSD) [1, 3]. One of the ways to improve the characteristics of LPE-based PSD, which are the LPE sensitivity and LPE nonlinearity as well as response times under pulsed illumination, is a select of the top layer material with high resistivity and with large work function [1, 3].

The **aim** of the research was to study the lateral photovoltaic effect in the TiO_2/SiO_2/Si structure with a low-conductive top layer in order to establish the lateral photoconductivity behavior.

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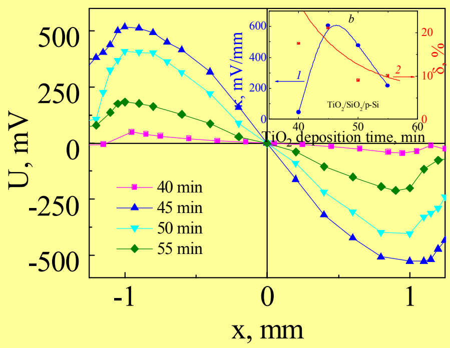
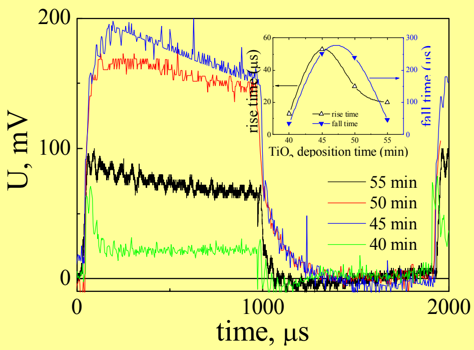
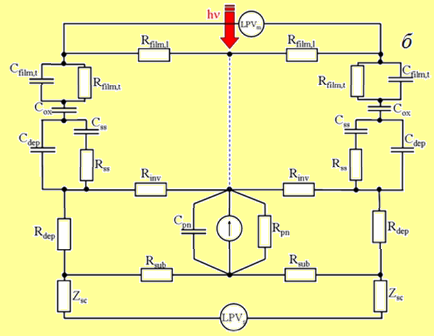
Experiment

TiO_2 films were formed on the oxidized silicon surface by the sol-gel method [4]. The silicon substrate were oxidized by boiling in the nitric acid for 5 minutes that results in the formation of the SiO_2 layer with thickness of ~1.5 nm. The LPE was done using He-Ne laser (0.3 mW, 633 nm) and Keithley 2000 multimeter. The TiO2 surface was partially illuminated by He-Ne laser spot with a diameter of about 60 μm. The LPV measurements have been carried out using the aluminum evaporated electrodes. The electrode distance is 2 mm. The rise time is defined as the time required to increase the photovoltage from 10% to 90% of the peak photovoltage (U_{max}), and the fall time is defined as the time required to reduce the photovoltage from 90% to 10% U_{max}.

Results and Discussion







The lateral photovoltage dependences on the laser spot position for the TiO_2/SiO_2/p-Si structure at different top layer thickness have different slope, that is, different sensitivity. The high LPE sensitivity in the TiO_2/SiO_2/p-Si heterostructure is due to the formation of a high built-in barrier at the SiO_2/p-Si interface, taking into account the energy characteristics of titanium dioxide and surface states at the interface. The thickness dependences of the LPE sensitivity and LPE nonlinearity allow one to determine the optimal TiO_2 film thickness. The maximum LPE sensitivity ~600 mV/mm is observed in the TiO_2/SiO_2/p-Si structure under the TiO_2 film deposition for 45 min. However, the LPE nonlinearity in this structure is 21%, which is concerned with the film morphological relief. A decrease of the LPE nonlinearity is achieved by the TiO_2 film thickness control. The LPE characteristics suitable for PSD are possessed by the structure fabricated by the TiO_2 film deposition for 50 min, in which the LPE sensitivity and LPE nonlinearity are 477 mV/mm and 9%, respectively.

The time dependences of LPV at a pulsed illumination are shown the photovoltage signal in the TiO_2/SiO_2/p-Si structure with a change of the top film thickness is characterized by both different pulse amplitude and different shape. The amplitude of the photoresponse signal varies in proportion to the change of LPE sensitivity. The change of the signal shape is related to the difference in the rates of excitation and quenching of photoconductivity in the TiO_2/SiO_2/p-Si structure at different thicknesses of the titanium dioxide film. Large value of time parameters in the TiO_2/SiO_2/p-Si heterostructure can be explained by the equivalent circuit. As in the heterostructure case a complementary RC-filter for the TiO_2 film is added to the RC-filter of the SiO_2/p-Si interface in the transverse direction, which slows down the photoresponse. The decrease of the signal amplitude U(t) may be explained by the reactance losses in the transverse direction of the structure in the contact region.

Summary

The presented results convincingly show the giant lateral photoconductivity in the TiO_2/SiO_2/p-Si heterostructure, in which the semi-insulator is used as the top layer, takes place due to the high built-in potential at the SiO_2/p-Si interface. Meanwhile, the lateral photoconductivity occurs along the inversion layer and near-contact regions, bypassing the film because of its high resistance. The LPE characteristics obtained during the study of the TiO_2/SiO_2/p-Si heterostructure make it possible to consider this structure as a promising candidate for optoelectronics.