Review Report for a Ph.D. Thesis submitted to St. Petersburg State University

Title: Enhanced charge carrier thermoemission from the dislocation-related electronic states in silicon

Author: Maxim V. Trushin

The review report provides 1) general comments, 2) evaluation statement and 3) specific comments and questions to the candidate

I. General Comments:

The research issue of the reviewed thesis is the electronic properties and defect states of dislocations in silicon. Despite of a long story of studying of dislocations in silicon, a new insight into the understanding of their properties was succeeded by the author due to the usage of a new, recently developed silicon wafer direct bonding technique, allowing to create regular dislocation networks (DN) with the predefined dislocation types, densities and the depth position below the front surface of the wafer.

The key tasks for the investigations were specified by the author as the influences of dislocation deformation potential, dislocation own charge and the potential of external electric field on the carrier thermoemission from the local electronic core states of screw and 60° dislocations in Si. Performing the comprehensive theoretical calculations, author has shown that the interaction of the attractive dislocation deformation potential with the external electric field results in the lowering of the potential barrier for carrier thermoemission in the way similar to the Poole-Frenkel mechanism known for Coulomb centers. The Poole-Frenkel coefficients due to the deformation potential of screw and 60° dislocation were calculated for carrier thermoemission towards the valence and conduction bands of Si and were found to exceed considerably the value for a Coulomb-like potential. Additionally, the influence of dislocation own charge on the carrier thermoemission was analyzed and the effect of emission enhancement with the number of captured carriers was demonstrated.

Experimental investigations were performed on n- and p-type bonded samples with different structures of dislocation networks. Deep level transient spectroscopy (DLTS) was applied as the main experimental technique to study the DN-related defect levels in Si band gap. Enhancement of carrier thermoemission was observed for the shallow levels located near the top of valence and the bottom of conduction band, respectively, which were identified with the shallow dislocation-related levels caused by deformation potential of 60° dislocations. In addition to the classical variant of DLTS method, the author has used isothermal DLTS method in order to register directly the variation of emission rate with the external electric field. Due to the planar location of DN in the investigated bonded samples, the electric field strength can be defined precisely. The observed emission enhancement was attributed to the Poole-Frenkel effect due to the strain field of 60° dislocations and a good agreement between the theoretically calculated and experimentally obtained values of the Poole-Frenkel coefficients was established. Besides, the decrease of the activation energy for carrier thermoemission with increase of the shallow states occupancy degree was revealed that coincides well with the theoretical curves following from the developed model. Author suggests an alternative explanation for the

broadening of the DLTS peak towards the lower temperatures as continues lowering of thermoemission barrier with the increase of the number of captured carriers.

II. Evaluation:

Novel theoretical and experimental results reported in PhD thesis of Maxim Trushin reflect a high level of professionalism of the author in the field of solid state physics and physics of semiconductors. I would say that the Ph.D. thesis written and submitted by Maxim Trushin can be accepted and doctoral degree can be awarded to the author.

III. Questions:

1. Author has interpreted the low-temperature DLTS peaks STn and STp as related with the deformation induced shallow 1D states of 60° dislocation. Whereas the DN in the investigated samples consists of both 60° and screw dislocations. So, what is with the DLTS signal from screw dislocations?

2. In Introduction, author said that the DNs may serve as an active element in all-Si light emitter with the operating wavelength of 1.5 μm. Which structural element of DN is then responsible for the radiative transition?

Reviewer

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