Free-carrier generation dynamics induced by ultrashort intense terahertz pulses in silicon

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The results of experimental studies and numerical simulation of the dynamics of the electron-hole pairs formation in silicon under the action of a two-period terahertz pulse with a maximum electric field strength of up to 23 MV/cm are presented. It is shown that an inhomogeneous distribution of the charge carrier concentration over the depth of the silicon sample is formed, which persists for several microseconds. This inhomogeneity is formed due to a sharp increase in the rate of filling the conduction band with free carriers in the subsurface input layer of the silicon wafer, which occurs at a field strength above 15 MV/cm.

The dynamics of filling the conduction band with free carriers was calculated using a model that takes into account an increase in the concentration of free carriers upon impact ionization. To calculate the time dependence of the conduction electrons concentration, we used differential equations based on Boltzmann equation in the frame of the Keldysh impact ionization model.

The developed model is in good agreement with the experimental results obtained in THz pump–optical probe geometry in p-doped silicon.

The possibility of a rapid change in the concentration of free carriers in the bulk of a silicon wafer (depending on the electric field strength of a THz pulse) makes it possible in the future to use the results obtained to create new high-speed optoelectronic devices.