Numerical analysis of formation of hexagonal and band structures in the gas discharge - semiconductor system

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The spontaneous formation of regular hexagonal and band structures in the current distribution of the gas discharge – semiconductor system is studied. The system consists of a planar glow discharge layer with short length in the forward direction and wide lateral dimensions, which is coupled to a planar semiconductor layer with low conductivity. The whole structure is sandwiched between two plane electrodes to which a dc voltage is applied.

The choice of input parameters is guided by the experimental study [1] and theoretical analysis [2]. The discharge is sustained in nitrogen at 28.2 kPa, in a gap of 0.44 mm. The semiconductor layer of thickness 0.1 mm of GaAs is assumed to have a homogeneous and field-independent conductivity $\sigma_s = 1.3\times10^{-8}\ \Omega^{-1}\ \mathrm{cm}^{-1}$ and dielectric constant $\varepsilon_s = 11.7$.

The model is based on the drift-diffusion theory of gas discharges. It includes the continuity equations for the electrons and positive ions, the energy balance equation for the background gas, and the Poisson's equation for the electrostatic field.

The linear stability analysis [3] is applied to develop the phase diagrams of transition of the system from the homogeneous to the structured state. Comparison with experimentally obtained phase transition diagrams allows to test different modelling approaches, where the particle fluxes include the drift only, both the drift and diffusion, and identify the effect of the gas heating. The full dynamical problem is also solved numerically as an initial value problem in one, two, and three space dimensions. This allows to test the result of the stability analysis, visualize the actual dynamics, and study the behavior beyond the range of the linear stability analysis.

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2. M.S. Mokrov and Yu. A. Raizer, "Simulation of current filamentation in a dc-driven planar gas discharge-semiconductor system", J. Phys. D: Appl. Phys. 44, 425202 (2011).

3. I. Rafatov, D.D. Sijacic, and U. Ebert, "Spatiotemporal patterns in a dc semiconductor-gas-discharge system: Stability analysis and full numerical solutions", Phys. Rev. E 76, 036206 (2007).