# Nonlinear Screening of Ferroelectric and Pyroelectric Films and Grains in Semiconductor Matrix

A. P. Dmitriev, V. Yu. Kachorovskii, and M. S. Shur
Rensselaer Polytechnic Institute, USA and A. F. Ioffe Physico-Technical Institute, Russia

Many novel semiconductor electronic and photonic devices use heterostructures, where strain induced and/or spontaneous polarization plays a key role. This polarization is screened by free carriers (*i.e.* electrons or holes), which form accumulation and depletion regions at the pyroelectric boundaries. These regions determine the device properties. For a single boundary between a semiconductor and a pyroelectric, the screening length is equal to the depletion region length in a semiconductor or to a few Debye lengths in the accumulation layer (depending on the direction of polarization and the doping type of the semiconductor. In this paper , we show that the depletion screening length is very different for relatively thin pyroelectric (or ferroelectric) films and grains in a semiconductor matrix. In most relevant cases, the depletion region width screening the polarization is shorter than for a single boundary and depends on the pyroelectric film thickness or on the radius of the pyroelectric grain. The reason is that the free carriers in the semiconductor are screening the polarization dipole rather than polarization charges on the two pyroelectric surfaces. These results are important for AlN/GaN/InN and SiC based electronic and photonic devices, ferroelectric random access memories, and ferroelectric semiconductor materials and devices.

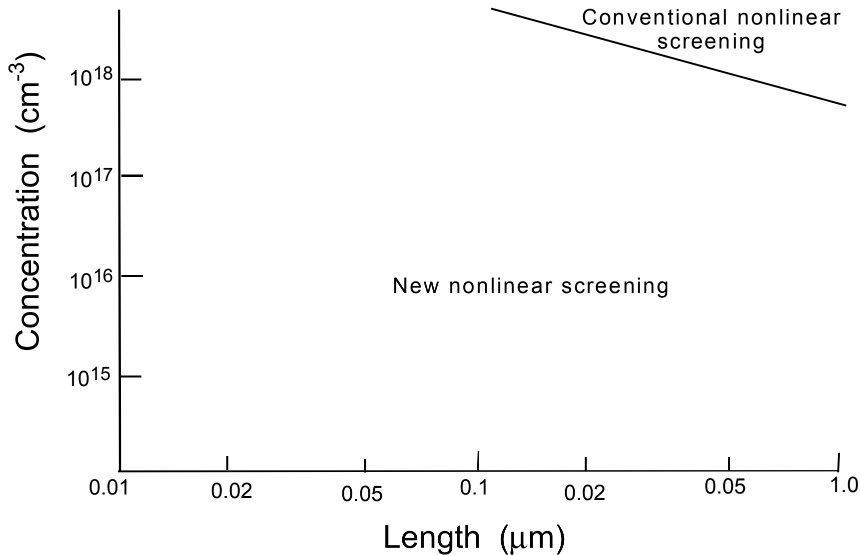


FIG. 1: Regions of "dipole screening" regime and conventional screening regime for AlN/GaN/AlN structure depicted in the ($n$, $L$) plane, where $n$ is electron concentration in semiconductor and $L$ is the width of pyroelectric film. As seen, the dipole screening regime takes place in most realistic cases.