Asymmetric Polarization Induced by Strong Electric Field on Spherical Semiconducting Particles

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A spherical conductive particle immersed in a uniform electric field acquires a charge distribution that displays odd symmetry with respect to the equatorial plane perpendicular to the applied field, while the internal field exhibits even symmetry. This configuration in symmetry is preserved in metal particles for a large intensity applied field, owing to the abundance in electrons. In extrinsic semiconductor particles, this symmetry is not maintained when the applied field approaches high intensity (~10^4 V/cm for a dopant concentration of 10^{17} cm^{-3}) as a result of depletion of mobile charge carriers (electrons or holes) in one of the hemispheres. While the mobile charges are able to congregate close to the surface on one side of the particle, the exposed dopant ions on the opposite side are unable to migrate, resulting in the broken symmetry when the applied field reaches a certain intensity.

A detailed study of the asymmetric charge distribution in an extrinsic semiconductor particle with doping ranging from 10^{15} to 10^{18} cm^{-3} under high intensity electric field is carried out by obtaining numerical solution to the Poisson-Boltzmann equation. Profiles of charge distribution and internal field within the particle are obtained, along with the induced dipole moment. Accompanying the asymmetry in charge distribution is a gradual reduction in the polarizability of the particle as the applied field intensity is increased. When a strong dynamic field is introduced, the polarization asymmetry leads to harmonics generation.

When a non-contacting particle pair formed from an n-type particle and a p-type particle is placed within a strong electric field, a polarization configuration with odd symmetry about the mid-point in the gap between the particles is displayed. A first principle calculation of the distant field given rise to by the polarization in the particle pair (in this case a bipolar dimer) reveals irreversible dependence of the secondary field on the orientation of the applied field. In addition to saturation effects due to charge depletion as observed in the single particle case, unequal amplitudes in the positive and negative half cycle of the waveform caused by field orientation dependent polarization contributes to harmonics generation by a particle pair in a strong dynamic field. Numerical solutions of the polarization in single and coupled pair of semiconductor particles are discussed in light of their dependence on carrier concentration and the intensity of the applied field. Inferences on strong field induced surface plasmon resonance in semiconductor nanoparticle and nanodimer will be drawn.