Recent developments in the theory of electrodynamic homogenization of random particulate systems

M.Ya. Sushko and A.K. Semenov

Mechnikov National University, 2 Dvoryanska St., 65026 Odesa, Ukraine, E–mail: mrs@onu.edu.ua

We present results [1-3], derived within the compact group approach (CGA) and effectively incorporating many-particle polarization and correlation effects, for the effective quasistatic dielectric constant/electrical conductivity of model dispersions of hard-core–penetrable-shell particles embedded in a continuous matrix. Both the cores and shells are characterized by radially symmetrical distributions of their electric parameters. The local properties of overlapping constituents are governed by the distance from a given point to the nearest particle.

Let x be an electric parameter of a system $\mathcal{D}$ and x_{eff} its effective value. The key points behind [1-3] are as follows:

(1) $\mathcal{D}$ is electrically equivalent to an auxiliary system $\mathcal{S}$ formed by embedding $\mathcal{D}$'s constituents into a uniform host with $x = x_{\mathrm{f}}$. $\mathcal{S}$ is a set of macroscopic regions (compact groups) large enough to have the properties of the entire $\mathcal{S}$, but point-like relative to the probing field;

(2) x_{eff} is found as the proportionality coefficient in the relevant constitutive relation between the averaged induction/current and field. These averages are expressed through the statistical moments $\langle (x - x_{\mathrm{f}})^n \rangle$;

(3) Combining the CGA with the Hashin-Shtrikman variational theorem or the boundary conditions for electric fields, x_{f} is proven to equal x_{eff}. This result makes the homogenization procedure internally closed;

(4) Finally, x_{eff}, as a functional of $\mathcal{D}$'s constituents conductivities and volume concentrations, is shown to obey an integral relation, rigorous in the quasistatic limit.

We demonstrate the validity of our results by: (a) contrasting them with analytical and numerical results for dispersions of graded dielectric spheres with power-law permittivity profiles; (b) mapping them onto extensive random resistor network simulation data for composite polymer electrolytes; and (c) applying them to real composite electrolytes.

[1] M. Ya. Sushko, *Phys. Rev. E* **96**, 062121 (2017).
[2] M. Ya. Sushko, A. K. Semenov, *J. Mol. Liq.* **279**, 677 (2019).
[3] M. Ya. Sushko, A. K. Semenov, arXiv:1811.10591 (2019).