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On consistency of classical homogenization

modelsforthepermittivityofstatisticallyhomogeneousmixtures

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The standard effective-medium methods to electrodynamic homogenization of heterogeneous media can be divided into two classes: symmetrical and asymmetrical. They are assumed to be independent and applicable to different types of systems, making a basis for different further modifications that take into account specific features of a given system. Despite the fact that these modifications are able to restore experimental data rather well, various authors note that the basic assumptions behind the methods are not consistent.

The goal of this report is to scrutinize these two homogenization methods, their consistency, and ranges of validity. To obtain the most general results, a simple system of impenetrable dielectric balls embedded in a uniform host medium has been considered. For its analysis, a generalized differential scheme was developed for the effective quasistatic permittivity of macroscopically homogeneous and isotropic dielectric mixtures [1]. The scheme is based upon the compact group approach (CGA) [2] reformulated in a way that allows one to analyze the role of different contributions to the effective permittivity of the system and modify it for different system structures.

It is shown that within the CGA, the only physically consistent homogenization type is symmetrical effective-medium homogenization. Applicability of this approach to the core-shell model and the description of numerical and experimental data for conductivity of composite electrolytes was demonstrated in [3]. The asymmetrical (differential) homogenization type can be obtained by replacing the electromagnetic interaction between previously added constituents and those being added by the interaction of the latter with recursively formed effective medium. Under this assumption, each portion of inclusions has different polarization, and the previously added portions do not interact with the new ones. This can be valid only for narrow concentration ranges and low contrast constituents, even for the generalized versions of the original mixing rules, as can be proved using the Hashin-Shtrikman bounds. Therefore, the asymmetric approach is approximate in the long-wave limit, and one should be cautious when using the differential models since they can lead to unpredictable errors and wrong results.

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[2] M. Ya. Sushko, *Zh. Eksp. Teor. Fiz.*, **132** (2007) 478 [*JETP* **105** (2007) 426]; *Phys. Rev. E* **96** (2017) 062121.

[3] M. Ya. Sushko, A. K. Semenov, *arXiv*:1810.11892 [cond-mat.mtrl-sci].

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