

The Effective Permittivity of a Composite Material

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From the pioneering work of Ottaviano-Fabrizio Mossotti, Rudolf Clausius, Ludvig Lorenz and Hendrik Lorentz, to the seminal Maxwell Garnett's equation and Bruggeman's mixing formulae, to the recent cluster models and analytical bounds, for nearly two centuries finding the effective permittivity of an inhomogeneous composite medium remains one of the key problems in electromagnetic theory. While some of the existing methods offer accurate results in special limiting cases (such as e.g. Maxwell Garnett's approach that is valid for non-percolating structures with small relative volume of inclusions), there is yet no theoretical approach that is applicable to a composite of arbitrary structure.

In the present work, we present the general analytical solution to this long-standing problem. We show that the permittivity of the composite is dominated by the universal contribution that only depends on the relative volume fractions of constituents, and present the analytical expressions for both the universal part of the permittivity and the non-universal correction due to the variations of the shape, size and spatial arrangements in the structure of the composite.