I. INTRODUCTION

Particle polarizability governs the electric response for many inhomogeneous systems ranging from biological cells to plasmonic nanoparticles and depends strongly on both its dielectric and geometric properties. Analytical models have been reported [1, 2] only for spherical and ellipsoidal geometries, whereas more complex geometries have been approached by direct numerical solution of the field equations using, for example, the finite difference methods [3], the finite element method [4], the boundary element method [5, 6], or the boundary integral equation (BIE) [7].

In a simplified representation, biological cells can be regarded as homogeneous particles (cores) covered by thin membranes (shells) of contrasting electric conductivities and permittivities. Complex geometries occur when cells are undergoing division cycles (e.g. budding yeasts) or are coupled in functional tissues (e.g. lining epithelia or myocardial syncytia). In these cases, the dielectric/impedance analysis of cellular systems is far more complicated than previous models [8–10], which considered suspensions of spherical particles. Intriguing dielectric spectra [11] reveal distinct dielectric dispersions with time evolutions consistently related to tissue functioning or alteration, identifying a possible role of cell connectors (gap junctions) in shaping the overall dielectric response.

A direct relation between the microscopic parameters and experimental data can be analytically derived only for dilute suspensions of particles of simple shapes, and is rather challenging for system with more realistic shapes, where only purely numerical solutions have been available. In this work we demonstrate that a spectral representation of a BIE provides the analytical structure for the polarizability of particles with a wide range of shapes and structures. The numerically calculated parameters encode particle's geometry information and are accessible by experiments.

By using single and double-layer potentials [12], the Laplace equation for the fields inside and outside the particle is transformed into an integral equation. A spectral representation for the solution of this equation is obtained providing the eigenvalue problem for the linear response operator is solved. Although not symmetric, this operator has a real spectrum bounded by -1/2 and 1/2 [13–15] and its eigenvectors are orthogonal to those of the conjugate double-layer operator. A matrix representation is obtained by using a finite basis of surface functions.