

MULTIPOLAR INTERACTIONS OF DIELECTRIC SPHERES

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Summary

The interactions of uncharged dielectric particles in an electric field can be described mathematically using multipolar expansions. Interparticle force calculations require that account be taken of the interactions of all these moments. Practical models for particle chains have been developed using a "dipole" approximation, where all moments except the dipole are neglected. To determine the accuracy of this dipole approximation, the effect of higher-order terms (quadrupole, octupole, etc.) upon the effective moment of particle chains is determined as a function of the number of particles in a chain, the relative dielectric constant ϵ_p/ϵ_m , and the spacing between particles d . It is found that the accuracy of the dipole model is severely compromised for closely spaced particles when $\epsilon_p/\epsilon_m > 4.0$, due to slow convergence of conventional multipolar expansions. Similar limits on the accuracy of the dipole model are found for short and long chains. For chains of touching spheres with $\epsilon_p/\epsilon_m \gg 1.0$, impracticably large numbers of terms are required to achieve convergence.

1. Introduction

The subject of this paper is the strong short-range electrostatic interactions induced between small uncharged dielectric particles in an electric field. These interactions may be represented by multipoles, including the familiar dipole and quadrupole plus other higher-order terms. Interparticle forces may be calculated by accounting for multipolar interactions which become very strong when particles approach each other in the presence of an electric field. Such calculations are essential to models for the electromechanics of systems of closely spaced particles in a variety of important physical situations.

In the present work, attention is restricted to chains of particles aligned parallel to the applied field. Particle chaining, reported as early as 1927 by Muth [1], is a ubiquitous and very important phenomenon. It has been observed in biological cells suspended in aqueous media [2], and is crucial to the success of cellular electrofusion as practiced by Zimmermann et al. [3]. It is