Electrokinetic flows about polarizable particles

In traditional electrokinetic analyses it is common to postulate a prescribed surface charge density (or, alternatively, zeta potential). Implicit in that approach is the assumption of ideally non-polarizable surfaces, which are not affected by externally applied fields. Clearly, such an assumption is inappropriate to describe flows about electrically conducting surfaces, which are effectively infinitely polarizable. It may even be inappropriate for dielectric surfaces, which do possess a finite polarizability. Following recent experiments in flows about electrodes, there is now an increasing interest in electrokinetic flows about polarizable surfaces, where Debye-layer charge is induced by externally applied fields.

As in the more traditional fixed-charge electrokinetic analyses, prevailing models of induced -charge flows usually employ the thin-Debye-layer limit. The electrokinetic transport occurring within the Debye layer is then effectively lumped into respective no-flux and slip boundary conditions, governing the electric and flow fields. The archetypical problem in such flows entails an *uncharged* conducting spherical particle (say a metal sphere) which is suspended in an unbounded fluid domain. When placed under an externally imposed Faraday current, the particle becomes polarized and a quadrupolar flow structure is formed.

Because of the high symmetry in that problem, the ensuing electrokinetic flow does not result in particle motion. Unsurprisingly, then, current interest lies in asymmetric configurations, which can result in electrophoretic motion of *zero-net-charge* particles. In the first part of the talk I will describe how asymptotic methods and symmetry arguments help in understanding this phenomenon.

For sub-micron particles, the thin-layer model breaks down. In the second part of the talk I will present a general analysis for an arbitrary layer thickness. Many of the electrokinetic concepts (e.g. zeta potential) associated with the thin-layer limit lose their concrete meaning in that general case, where instead of slip-driven *electro-osmosis* one encounters force-driven *electro-convection*. Thus, a systematic investigation of the electro-kinetic flow requires a confrontation with the highly-coupled nonlinear electrokinetic equations. Fortunately, the small particle size allows linearization with respect to the external field intensity. Of special interest is the *thick*-Debye-layer limit, which applies to nano-particles. This limit is singular and requires a systematic use of inner-outer asymptotic expansions, in the spirit of Proudman & Pearson (1957).