ABSTRACT

In the current thesis, a few yet to be addressed problems pertinent to the electrokinetic phenomenon (especially streaming potential and dielectrophoresis) in a randomly oriented porous matrix is reported.

Electrokinetics has turned out to be an effective means towards dictating the underlying functional success, which in turn depends on the electrical double layer (EDL) phenomenon. Probing the underlying consequences effectively requires an electrochemical characterization of the EDL, which typically necessitates elaborate experimental arrangements. Obviating the limitations of the traditional electrochemical characterization techniques; here an alternative frugal technique is studied to characterize the channel resistance and EDL parameters, including the zeta potential, of a 'paper-and-pencil' based microfluidic device. The present methodology will more generically emerge as an effective substitute for 'Electrochemical Impedance Spectroscopy (EIS)' and 'surface analyzer' for measuring electrochemical parameters of a micro or nanofluidic device. On the other hand, the presence of sub-nanometric size pores in cellulose fiber provides a facile means of studying ion transport, eradicating the sophisticated laboratory protocols reported in the literature. The experimentally induced streaming potential value unveils a strong dependency on the ion hydration size possibly due to the stick-slip transition at the solid-liquid interfaces depending on the level of water structuration. Furthermore, the 'charge inversion' phenomenon is observed to be a function of tri-valent species. These fundamental outcomes would possibly provide insights in improving the device performance subjected to different electrolytic environments. Thus, the performance of such devices can be improved with a maximum electrical potential up to ~2.1 V (corresponding output power of ~50 nW) through multiplexing, while maintaining the device efficiency for more than 12 days. However, the device performance is often constrained by the degradation and eventual disintegration of the paper fibers under continuous exposure to a wetting liquid. To circumvent such issue, a centimeter-sized simple wet fabric piece is further considered for continuous electrical power generation, by deploying the interplay of a spontaneously induced ionic motion across fabric nanopores due to capillary action and simultaneous water evaporation by drawing thermal energy from the ambient. The device is capable of generating a sustainable open-circuit potential up to ~12 V with small-scale multiplexing that is further used to power a white LED for more than 1 hour. In a different study, a ‘paper-and-pencil’ based platform is used to study for controlled entrapment of microparticles or biological cells using dielectrophoresis (DEP). In sharp contrast to other reported traditional DEP devices, the present configuration does not demand any sophisticated laboratory module for creating a non-uniform electric field, which is an essential requirement in DEP settings. The study brings out an optimum range of medium pH for efficient trapping. The device further shows flexibility in selective and yet, localized trapping with considerably a lower electric field than that reported in the literature. This provides the basis of being considered to constitute the fundamental premises of designing a flexible pre-concentrator device for different bio-analytical signal detection systems in a low-cost paradigm.

Keywords: ‘Paper-and-Pencil’ microfluidics, electrical double layer, zeta potential, streaming potential, electrokinetic energy conversion, ion hydration, fabric channel, fabric nanopores, capillarity-coupled-evaporation, dielectrophoresis, particle trapping.