

Conducting polymers for ion extraction from aqueous solutions

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Pure water is a globally significant commodity. It is widely known that the presence of some ionic contaminants in water and wastewater causes serious environmental and health problems. In contrast to e.g. neutral organic contaminants, which can undergo biodegradation, many ionic pollutants remain in the environment, and their speciation and bioavailability might change over time. They can enter the food chain and accumulate in living organisms. To this end, specific instances in which water purification is important include environmental remediation, industrial processes and, critically, water for human consumption.

Conducting polymers are attractive materials for use in a variety of applications that require materials which are both electrically conducting and mechanically compliant, *i.e.* in energy conversion/storage, sensing applications and supplement the quest for powerful yet small/thin and flexible devices. Most of the above devices work in an electrochemical environment and can be considered to be “modified electrodes”. One of the most notable features of the conducting polymers is the potential-dependent variation of their charging state. It can, in principle, be applied to remove ionic species including organic ones (such as metabolites of medicines, neurotransmitters, antibiotics *etc.*) that are potentially harmful to the environment and human health from aqueous solutions (including wastewater, drinking and groundwater) via stripping, and release those by changing the charging state of the polymer layer. In principle, conductive polymer-coated electrodes may be used as “intelligent” stationary phases of separation columns. Similarly, it is possible to regulate the dosage of different medicines even *in vivo*.

The electrochemically controlled ion extraction by electrochemically active films (modified electrodes) for water purification has already been considered sporadically in the literature [1,2], but not in a systematic way, and the scenarios described are rather restricted. As a consequence, the available experimental results are contradictory and do not give sufficient or definite evidence regarding the reliability, validity and feasibility of the methods used.

The following questions arise regarding the applicability of the proposed methods: 1) What is the effectiveness of electrochemically active polymer films and polymer composites (*i.e.* modified electrodes) in the electrochemical detection and removal of ionic species? 2) Which are the most effective materials (conducting polymers, substrates, *etc.*) and procedures for the electrochemically controlled ion extraction? 3) Since the stability of polymer films is one of the most serious problems in applications, it is extremely important to find out how to stabilize the applied films.

The main objective of the work presented in this study is to answer the above questions based on systematic (laboratory scale) experimental and theoretical studies. We discuss our results obtained with different polymers, more precisely with PEDOT (Poly(3,4-ethylenedioxythiophene)) and three polymer blends (or macromolecular salts): PEDOT:PSS (PSS: polystyrene sulfonate) [3], PEDOT:SDS (SDS: Sodium Dodecyl Sulfate) [4], and PEDOT:DS (DS: dextran sulfate) [5]. One of the biggest problems during the experiments is the stability of the films. It could be shown that conducting polymer films reinforced with non-conducting polymers are more resistant to degradation that may occur during the process [6,7]. That is, the reinforcement is “mechanical” in nature (thus referred to as “mechanical reinforcement”, as well) because the reinforcing polymer “fixes” the conducting polymer layers that tend to delaminate from the substrate. In addition, it protects the conducting polymer layer as a non-enclosed cover layer but does not completely close it from the environment, allowing the conducting polymer to contact the medium surrounding it.

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