The influence of electric fields on the adsorption dynamics and conformation of biofilm-related polymers

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Introduction

The range of environments in which microorganisms thrive is wide, and in most cases, their biofilm presence is undesirable in most water and wastewater treatment systems. In processes that involve membranes, electrodes and other conductive and non-conductive surfaces, the formation of a biofilm layer hampers their proper functioning. The adverse effect of biofilms is mainly associated with changes in mass (Radu et al. 2010) and heat (Characklis et al. 1981) transfer properties as well as surface morphology alterations. As an example, biofilm formation could lead to reduced sorption capacity of electrodes in capacitive deionization (Suss et al. 2015). A previous study (Gall et al. 2013) confirmed that electric fields have an effect on bacterial attachment and biofilm formation, but a thorough investigation of the mechanisms has yet to be done. In this study, we study the adsorption dynamics of alginate, a polysaccharide of importance in *Pseudomonas aeruginosa* PAO1 biofilms, as well as the adsorption dynamics of extracellular polymeric substances (EPS) produced from wild type and a mucoid strain of *P. aeruginosa* under the influence of electric fields. We aim to elucidate the interfacial behaviour of alginate under applied electric fields and show that even though it is not a major component of the EPS (Wozniak et al. 2003), it has an important role in determining its adsorption behaviour under applied electric fields.

Materials and Methods

We use a Quartz Crystal Microbalance with Dissipation (QCM-D) (Reviakine et al. 2011) equipped with an electrochemical flow cell to follow adsorption dynamics on a gold coated sensor. The electrochemical setup is complete with an Ag/AgCl reference electrode and a platinum sheet serving as a counter electrode. High viscosity- and very low viscosity-sodium alginate (AlfaAesar) solutions of 0.1%w/v at pH8 in a background electrolyte solution of 10 and 100mM NaCl were injected into the QCM-D flow module. EPS from biofilms of *P. aeruginosa* PAO1 was extracted from both strains mentioned, after 48 hours of growth in a packed bed column (glass beads), fed with an LB broth feed solution.

Results and Discussion

The adsorbed high viscosity alginate (HVA) exhibits small responses to the applied voltage, in contrast to the very low viscosity alginate (VLVA) that shows interesting behaviour under similar conditions. Both solutions (in 10mM & 100mM NaCl) of VLVA show an increased adsorption when a positive voltage is applied, which is expected due to the negative charge of alginate. A result of important consequence is the reaction of the VLVA in 10mM NaCl under a negative voltage. Under these conditions, there is an almost-immediate desorption of alginate. Likely, this desorption is due to the decreased electrostatic shielding occurring under a weaker ionic atmosphere. Furthermore, we see in longer adsorption experiments over 2.5 hours that VLVA exhibits a unique behaviour of continuous linear adsorption whereas HVA does not (figure 1). When studying EPS of wild type and a mucoid strain, similar adsorption behaviour of the PAO1 wild type EPS was observed with and without applied electric fields. On the contrary, EPS produced by a mucoid strain exhibited increased adsorption under applied electric fields, confirming the important effect of alginate, once produced.

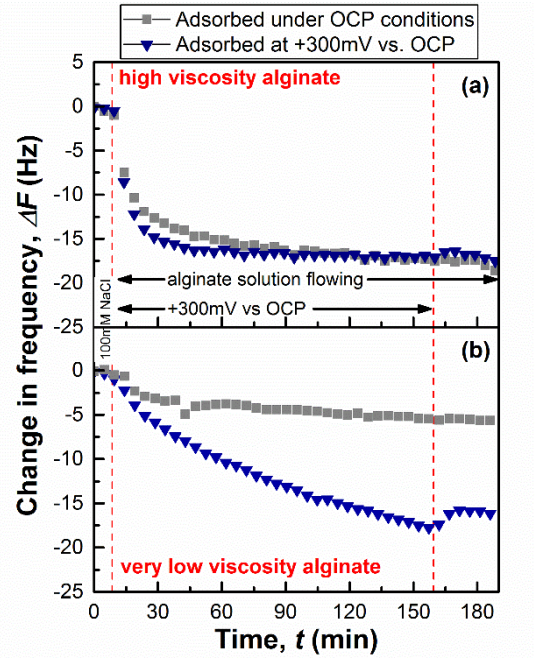


Figure 1. Alginate adsorption dynamics under both applied potential (+300 mV and open circuit potential (OCP) conditions: Adsorption of high viscosity (a) and very low viscosity (b) alginate.

Conclusions

Our results show clear dependence of the behaviour of adsorbed alginate on both the ionic atmospheres (10 and 100 mM NaCl) and molecular weight. We show that under conditions of that are accessible in water treatment systems, it is possible to cause desorption of alginate to a certain extent.

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