Assessment of Protein-Biomaterial Surface Interaction by Streaming Potential Measurement

T. Luxbacher

Anton Paar GmbH, Anton-Paar-Strasse 20, 8054 Graz, Austria

Introduction: The knowledge of surface charge and the isoelectric point is important for many biomedical applications. The zeta potential, formally defined as the electrical potential at the electrokinetic plane of shear, is an important property of charged solid/liquid interfaces and a descriptor of the actual surface charge of a solid immersed in a dielectric. For macroscopic solid surfaces, the zeta potential is commonly determined by the measurement of streaming potential and streaming current. The versatility of the streaming potential method allows handling of planar surfaces, cylindrical capillaries, and packed beds of granular or fibrous materials. The family of biomaterials consists of all of these types of materials like biosensors with a planar surface, hollow fiber membranes for haemodialysis, chitosan nanofibers for skin replacement, or biopolymer beads for pharmaceutical application.

Besides the evaluation of the charging behavior of such biomaterial surfaces, the zeta potential is a valuable indicator for surface stability in the presence of various liquids, and for the adsorption of proteins, polypeptides, and other biomacromolecules on biomaterials' surfaces. In this paper the application of the streaming potential method in the field of biomaterials' surface characterization is presented with different case studies.

Methods: Streaming potential and streaming current measurements were performed with the SurPASS electrokinetic analyzer (Anton Paar GmbH, Graz, Austria) in the presence of an aqueous solution of KCl or PBS with an ionic strength of 1 mmol/l at different pH.

The zeta potential was determined on various types of biomaterial model surfaces such as disks of glass and titanium with 14 mm diameter, polysulfone membranes (flat sheet and hollow fiber), and rectangular silicon wafer pieces with 20 mm × 10 mm.

Results: The approach of the streaming potential measurement for the characterization of biomaterial surfaces is strictly related to boundary conditions determined by the stability of the surface when exposed to an aqueous solution. For stable surfaces, the material is equilibrated in the measuring electrolyte first before starting the measurement. When dissolution of a coating or chemical reaction of the surface with acids or alkaline solutions are expected or observed, the time dependence of streaming potential gives information about the kinetics of these surface processes.

Besides a standard titration of surface functional groups and the detection of dissociation and protonation of these groups by recording the pH dependence of zeta potential, the interaction of dissolved components, such as proteins, with the solid surface is observed at increasing concentration of these components in the electrolyte.

By the combination of adsorption studies with surface titration, the presence of protein layers on solid substrates may be confirmed. As an example figure 1 shows the pH dependence of zeta potential for untreated glass and titanium, respectively. Glass shows an acidic surface determined by the presence of silanol groups (Si–OH). Titanium is covered with a native oxide layer and this titania surface behaves amphoteric when exposed to the aqueous electrolyte solution.

After exposure to a solution of bovine serum albumin (BSA) in PBS (50 µg/ml) both the glass and titania surfaces get equally coated by a BSA layer. This conclusion is confirmed by the comparison of the isoelectric point (IEP, pH where $\zeta = 0$ mV) of glass and titanium in the presence of BSA with the IEP of BSA in solution at pH 4.7.

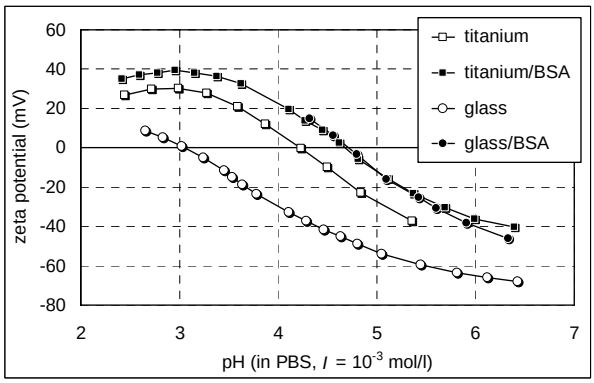

Figure 1. pH dependence of zeta potential for glass and titanium in the presence of BSA

Conclusions: The measurement of streaming potential and streaming current is a conclusive method for the characterization of surface treatment of biomaterials, e.g., to enhance their biocompatibility. It allows a direct investigation of the interaction of biological compounds with all kinds of biomaterials.