

Effect of the flow state on streaming current

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Streaming current is the source of the streaming potential, which is one of the electrokinetic phenomena, and results from fluid flow which transports the charge in the electric double layer. In the classical Helmholtz-Smoluchowski relation, the streaming current (I_s) is represented as $I_s = C_c * \text{grad } P_p$, where C_c is streaming current coefficient and P_p is fluid pressure. Zeta potential is the potential at the slipping plane near the solid-liquid interface and important factor controlling the streaming current coefficient.

In the previous study (Kuwano et al., 2004, Joint Meeting for JEPS), we reported the apparent grain size dependence of zeta potential, which was unexpected from the nature of zeta potential. We set up two hypotheses to explain this effect. One is that new surfaces which have been created by crushing the sample may affect the zeta potential. We thought if newly created surfaces have higher zeta potential in magnitude, samples of smaller grain size which have more new surface area will have higher apparent zeta potentials obtained from streaming potential measurement. Another is that the state of fluid flow may affect the zeta potential. The equation which is used to infer the zeta potential is derived in the condition of laminar flow. State of flow tends to be out from laminar flow at high flow rate or large grain size. In the present study, we examined the effect of state of fluid flow on apparent zeta potential.

In order to measure how state of flow affects magnitude of the streaming current, measurements need to be conducted by the various flow rates and various sizes of particles on the same condition of the surface. So we chose various sizes of soda-lime glass beads as samples. Grain sizes of the soda-lime glass beads are 0.177-0.250 mm (GB200), 0.350-0.500 mm (GB400), and 0.710-0.990 mm (GB800). These samples are soaked in acetone for 12 hours, adequately washed with acetone several times, washed with distilled water and with KCl solution which was used for background electrolyte, and soaked in KCl solution at least 24 hours until measurement. In this experiment, we measured the streaming current and the flow rate.

The results were as follows. Apparent zeta potential was clearly affected by state of flow; it decreased when Reynolds number (grain diameter was adopted as characteristic length) was larger than 1~10. This is due to a mechanical effect in the flow rate-driving pressure relation, not a chemical effect on the zeta potential. This effect of state of fluid flow can explain the apparent grain size dependency. However, the decreasing rate of the streaming current is much smaller than that of the flow rate. It means that turbulent flow induces more streaming current per unit flow rate.