Soft-particle gel electrophoresis

Particle electrophoresis in free solution or in gel media is a powerful technique for characterizing the surface properties of colloidal particles. Particle gel electrophoresis, that is, transport processes of colloidal particles in polymer gel media under an applied electric field is quite different from usual particle electrophoresis in free solutions. There are two types of interactions acting between the particle and the surrounding gel medium when the particle is migrating through the pores of a gel matrix, that is, the short-range steric interaction due to the particle-gel friction and the long-range hydrodynamic interaction. For dense gels, where the particle size is larger than the pore size in a gel medium, the steric effect is dominant and a reputation theory can be applied. For dilute gels, on the other hand, where the particle size is much smaller than the gel pore size, the long-range hydrodynamic interaction between the particle and the gel medium must be taken into account.

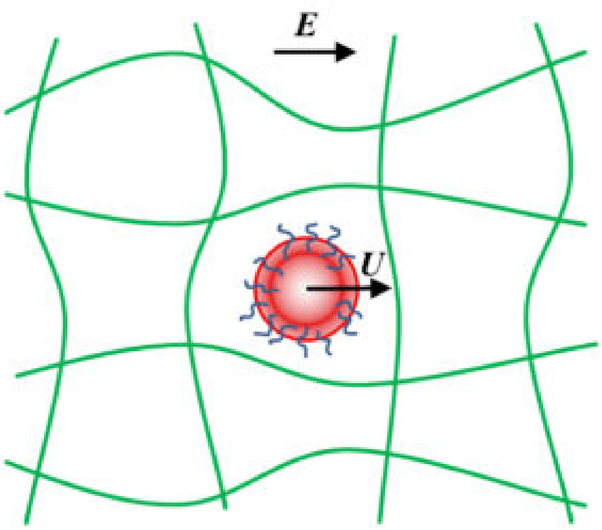

Fig. 1. Soft-particle gel electrophoresis.

The electrophoretic mobility of a particle in a dilute gel medium is shown to be expressed as the product of the electrophoretic mobility due to the long-range hydrodynamic interaction and a factor representing the steric effect. We focus on the electrophoretic mobility of a soft particle in a gel medium due to the long-range hydrodynamic interaction. There are many theoretical studies on this electrophoresis problem. Most of these studies treat the network of cross-linked polymer segments as a porous skeleton saturated with an electrolyte solution and employ an effective medium approach, which are based on the Brinkman-Debye-Bueche model. In this model, polymer segments in the gel medium are regarded as resistance centers, exerting frictional forces on the liquid flowing in the gel medium. Note that for a charged gel, there is an electroosmotic flow, which is in the opposite direction or in the same direction to the particle movement depending on whether the particle and the gel are likely charged or oppositely charged. Allison et al., in particular, considered the particle gel electrophoresis in uncharged gel media on the basis of the Brinkman-Debye-Bueche model and derived electrophoretic mobility expressions. Li, Hill and others extended the theory of Allison et al. to the electrophoresis in charged gel media. Ohshima derived a simple analytic expression for the electrophoretic mobility of a particle in a charged or uncharged polymer gel medium. Li, Allison, Hill and others developed a theory of the gel electrophoresis of a soft particle, i.e., a hard particle covered with an ion-penetrable surface layer of polyelectrolytes.

The electrophoresis theory of soft particles in a free electrolyte solution is also based on the Brinkman-Debye-Bueche model. In the above theory of gel electrophoresis of soft particles, the Brinkman-Debye-Bueche model is equally applied to the internal region of the polyelectrolyte layer and the polymer gel medium. That is, polymer segments within the polyelectrolyte layer of a soft particle are regarded as resistance centers, exerting frictional forces on the liquid flowing in the polyelectrolyte layer. The only difference is that the polymer segments in the polyelectrolyte layer move at the same velocity as that of the core of the soft particle, while on the other hand the polymer segments in the polymer gel medium are fixed in the medium. We have made a detailed study on the gel electrophoresis of a soft particle in an uncharged or charged polymer gel medium under an external DC electric field with special emphasis on analytic expressions for the electrophoretic mobility. A general expression and several approximate analytic expressions were derived for the electrophoretic mobility of a soft particle in a polymer gel medium.

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