

Diffusion enhancement of chemically driven molecular motors

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The Brownian motion of a particle subject to a periodic potential is suppressed due to the potential barrier. Therefore, it is surprising to see that the application of a constant external force to such a system in one dimension can greatly enhance the diffusion compared to the free diffusion [1]. The enhancement occurs if the magnitude of the force is close to the maximum slope of the potential. In this situation, the particle hesitates whether to stay or to go when it comes close to one of the locations of maximum slope, which results in the increase in the variance of the particle position and hence increase in the diffusion coefficient. This phenomenon was observed in F_1 -ATPase, a biological rotary motor, in the absence of adenosine triphosphate (ATP), the fuel molecule for this motor [2]. The rotor of F_1 -ATPase is subject to a periodic potential due to the interaction with the stator of three-fold symmetric structure, and it was forced to rotate by a constant external torque. From the value of the torque at which the largest enhancement in the rotational diffusion occurs the strength of the rotor-stator interaction was inferred.

The purpose of our study is to demonstrate another mechanism of diffusion enhancement for a related system, a model for molecular motors driven by chemical reactions, and to suggest that this phenomenon can be observed in F_1 -ATPase. The model consists of a Brownian particle and potential wells placed periodically on a line; the particle is subject to one of these at a time. The potential acting on the particle switches to either of the adjacent wells on the right and left by a chemical reaction (ATP hydrolysis or synthesis). This potential switching, which corresponds to a conformational change in a motor protein, results in a unidirectional motion of the particle. We have numerically calculated the diffusion coefficient of this model in the presence of a constant external force. It turns out that if the switching rates depend on the particle position in an appropriate way the diffusion coefficient as a function of the external force exhibits peaks (i.e., diffusion enhancement occurs) and the peak position depends on the ATP concentration and other parameters. The diffusion enhancement results from the competition between the potential switching and the relaxation of the particle in a potential well. Some results of our work have been reported in Ref. [3].

[1] P. Reimann et al., Phys. Rev. Lett. **87**, 010602 (2001).

[2] R. Hayashi et al., Phys. Rev. Lett. **114**, 248101 (2015).

[3] R. Shinagawa and K. Sasaki, J. Phys. Soc. Jpn. **85**, 064004 (2016).