Characterization and Tuning of Slip Flow on Graphene

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論　文　内　容　の　要　旨
Thesis summary

Slip flow can be used to decrease the flow resistance inside a channel, which has a great potential for energy harvesting, water desalination, and micro/nano scale cooling devices. Slip length is usually used to determine the ability of a fluid to slip on a solid surface. However, the slip length in previous research is scattered in a large range, and the mechanism of this large scattering is still not unambiguously studied. Therefore, this thesis is focused on studying the slip flow on graphene surface by measuring slip length on graphene with various liquids and studying the possible factor which could affect the slip length.

This thesis is composed of five chapters. The general background on the slip flow on graphene surfaces has been introduced and previous simulation work had been summarized into three categories, including graphene characteristics, liquid characteristics, and solid/liquid interaction. Research using an experimental approach was also introduced, including the AFM measurement method and capillary filling method.

The second chapter introduces the fabrication methods for making the graphene nanochannel used in this thesis and the flow measurement procedure when observing the capillary filling. The fabrication methods include the nanochannel fabrication and wet transferring method to transfer graphene from copper to nanochannel. Flow movement was measured by setting a high-speed camera on top of the channels.

The third chapter introduces the development of the three-dimensional flow model which fully considers the effect of 3D velocity profile, slip velocities, and contact angles on different channel walls. The analytical results show that the 3D effect in the channel cannot be neglected even in a channel with a width/depth ratio larger than 100. The slip length of 40 ± 4 nm and 33 ± 3 nm were measured in our self-fabricated graphene nanochannels. The 3D model developed in this thesis was also used to reanalysis previous experimental research which used a 2D model to calculate slip length. This thesis corrected the slip length from 45 ± 2 nm to 30 ± 5 nm and from 60 ± 20 nm to 47 ± 16 nm. The results of the water slip length on graphene approximately fall in the range of 30 to 50 nm, which is closed to some previous important simulation research.

The fourth chapter introduces the investigation of slip length dependent on surface charge density. The methodology to modulate the slip length on graphene by altering the surface charge density is introduced first. Follow up by the contact angle measurement as its value will be altered under different surface charge densities. The contact angle of both water and 0.1M KCl solution decrease as surface charge density increase. However, a larger variation of the contact angle of 0.1M KCl solution was found and it’s due to the higher density of ions near the graphene surface. This caused the surface tension between solid and liquid to

decrease and leads to a smaller contact angle. Last but not least, the relationship between the slip length and surface charge density was investigated. Water, 0.1M KCl solution, and ethanol were used in this investigation and there are four important findings in this thesis: First, the ethanol shows the highest slip length due to the adsorption layer form on the graphene surface, which caused a smaller friction coefficient and leads to a higher slip length. Next, the slip length of ethanol didn't decrease with surface charge density as the binding between the ethanol molecules and the charged site is weak. The weaker binding is due to ethanol having a much smaller relative polarity. Third, the slip length of water and 0.1M KCl solution decreased with surface charge density as they possessed larger relative polarity and lead to a stronger binding with the charged sites. Last, the model predicting the slip length decrement with surface charge density on a heterogeneous charged surface was fitted with the results of our experiments with a different value of hydrodynamic diameter. The variation in hydrodynamic diameter is due to the inevitable contamination and quality difference on the graphene surface.

All the work done in this thesis and some future works were introduced in chapter 5.

〔作成要領〕

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