[P2.070]

Numerical studies of dynamic droplet moving for fluid analysis of biosensor

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Background: The growing demand for compact biosensor devices for analysing of human samples such as protein, mRNA and DNA on the micro- or nano-liter scale has recently seen the development of the concept of lab-on-a-chip and micro total analysis systems (μTAS). However, a theory which can enable to calculate the dynamic droplet moving does not exist. We propose a dynamic contact angle model in order to investigate a water droplet moving behaviour numerically onto a flow channel of biosensor.

Materials and Methods: The numerical simulation uses the experimentally observed droplet behaviour and a dynamic contact angle model based on experimentally observations. The experimental system was consisted from a high speed camera (HX-6, Nac Image Technology, Japan) and a contact angle calculating software (Tangent Method, Ditect Co., Japan). Pictures of 320 × 24 pixcels at a frame rate of 300,000 fps (3.33 μs/frame) were recorded. Distilled water was used as the sample liquid and the substrate was a silicon wafer whose equivalent contact angle, θ_e, was 90°.

Results and Discussion: A characteristic between the contact angle, θ, and the velocity of triple point, v, was obtained experimentally (Fig.1). An approximation to the experimental data was proposed as a dynamic contact angle model as follows:

$$\theta(v) = \min\left[\theta_e\left(\frac{C_a}{k_a}\right)^{\frac{1}{3}},\ \theta_{mda}\right] \text{ if } v \geq 0, = \max\left[\theta_e\left(\frac{C_a}{k_r}\right)^{\frac{1}{3}},\ \theta_{mdr}\right] \text{ if } v < 0 \quad (1)$$

where, C_a is the Capillary number, k_a and k_r are material related consistants for advancing and receding, θ_{mda} and θ_{mdr} are maximum and minimum of dynamic contact angle, respectively. Finally, a computational fluid dynamics simulation obtained by solving the Navier-Stokes equation was used (Stream, Software Cradle Co., Ltd., Japan) to calculate the dynamic droplet moving. A comparison between the measured and the numerical results for water droplet moving behaviour was shown in Fig.2.

Conclusion: It was considered that precise dynamic contact angle modelling play an important role in the modelling of droplet moving behaviour.

A: A droplet and the velocity of triple point

Keywords: numerical simulation, dynamic analysis, contact angle, flow

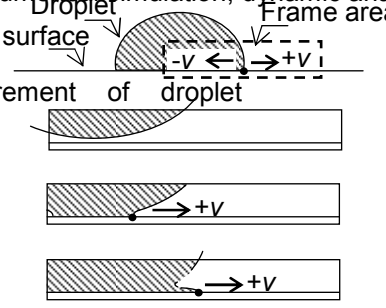

Fig.1 Schematic diagram of measurement method for the dynamic contact angles.

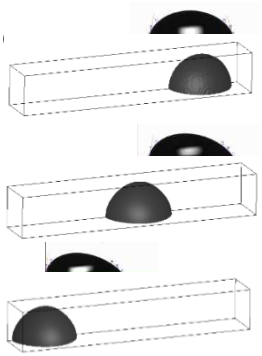

Fig.2 Comparison of dynamic droplet moving between measured (upper) and calculated (lower) results.