S3: Advances in Hemorheological Measurements-I

S3-1 Holotomography techniques for imaging 3D label-free imaging of cells and tissues

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Quantitative phase imaging (QPI) has emerged as an invaluable tool for imaging small transparent objects, such as biological cells and tissues. QPI employs various interferometric microscopy techniques to quantitatively measure the optical phase delay of samples. In particular, the measured optical phase delay provides information about the morphological and biochemical properties of biological samples at the single-cell level. Recently, QPI techniques have been widely applied to study the pathophysiology of various biological cells and tissues, including red blood cells (RBCs), white blood cells, bacteria, neurons, and cancer cells. In this talk, we will present the recently developed 3-D holotomography setup using a dynamic mirror device, which is an optical analogous to X-ray computed tomography. In particular, we will discuss the visualization of 3D refractive index distributions of biological cells and tissues measured with the 3-D holotomography using the transfer function method, which has been widely used in the visualization field [1-4]. In particular, we will present recent updated on the application of holotomography techniques for the study of various blood-cell-related diseases, including general hematology, malaria, babesia infection, blood cells of diabetes patients, and immune cell diseases. In addition, we will also present the optical manipulation of eukaryotic cells on demands exploiting 3-D refractive index tomography [5-6]. [1] K. Lee et al., Sensors 13, 4170 (2013). [2] S. Shin, K. Kim, J. Yoon, and Y. Park, Optics Letters 40, 5407 (2015). [3] K. Kim, K. Choe, I. Park, P. Kim, and Y. Park, Scientific reports 6 (2016). [4] P. Hosseini et al., Proceedings of the National Academy of Sciences, 201610435 (2016). [5] Lee SY, Park HJ, Kim K, Sohn YH, Jang S, Park YK, Scientific Reports, 7:1039 (2017) [6] K. Kim and Y. Park, Nature Communications, 8:15340 (2017).

S3-2 A microfluidic device for simultaneous measurement of blood viscosity, hematocrit, and deformability

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An elevated whole blood viscosity is related to the cardiovascular diseases including diabetes, hypertension, stroke and so on. And, there are many reasons for elevated viscosity of blood. Especially, whole blood viscosity is strongly dependent to the physical properties of red blood cells e.g., hematocrit, deformability. In this study, a microfluidic device enabling to measure the whole blood viscosity, hematocrit and red blood cell deformability is proposed for multimodal analysis of physical characteristics of whole blood.

The proposed device is composed of hydrodynamic and electronic parts. In a hydrodynamic part, it has ten microchannel arrays which can generate the multiple sets of shear rate. Once the whole blood is infused with PBS as a reference fluid, viscosity of whole blood can be estimated by comparing the number of channels filled with blood and PBS. In an electronic part, there is a PCB device having a pair of electrodes on the opposite sidewalls for acquiring impedance spectrum of blood. Hematocrit is estimated by comparing the resistances of cytoplasm and plasma. And, deformability is evaluated by changing membrane capacitance.

From experimental demonstration, Ten sets of blood viscosity over 100 – 1,000 /s in are acquired and it shows 3.7 % in relative error compared to the rotational rheometer. And multiple hematocrit level can be accurately measured with 1.5 % in relative error. It shows

good linearity with 1.02 in slope compared to the centrifuge. For evaluating cell deformability, glutaraldehyde solution is added to the blood sample for hardened red blood cells. Change in constant phase element (CPE) of normal sample at 100 and 500 /s is 1195.6. And hardened sample shows 247.9 which is 4.8 times smaller than normal sample.

S3-3 Deformability measurement of continuous soft particles by lattice Boltzmann method and its applications to rheological flow characteristics

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Technologies that use optical force to actively control particles in microchannels are a significant area of research interest in various fields. An optical force is generated by the momentum change caused by the refraction and reflection of light and changes the particle surface as a function of the angle of incidence of light, which in turn feeds back and modifies the force on the particle. Simulating this phenomenon is a complex task. The deformation of a particle, the interaction between the surrounding fluid and the particle, and the reflection and refection of light should be analyzed simultaneously. Herein, a deformable particle in a microchannel subjected to optical interactions is simulated using the three-dimensional (3D) lattice Boltzmann immersed-boundary method. The laser beam from the optical source is analyzed by dividing it into individual rays. To calculate the optical forces exerted on the particle, the intensity, momentum, and ray direction are calculated. The optical-separator problem with one optical source is analyzed by measuring the traveled distance because of the optical force. The optical-stretcher problem with two optical sources is then studied by analyzing the relation between the intensity of the optical source and particle deformation. This simulation will help the design of sorting and measuring by optical force.

S3-4 A microfluidic platelet assaying device for function test and antiplatelet response test

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Aggregation and adhesion of platelets to the vascular wall play critical roles in hemostasis and thrombosis. The present study introduced a microfluidic device and method to test platelet functions corresponding to various agonists and shear rates. A shearing activation of platelets was induced by a rotating flat bar in a sample chamber and the shearing-magnitude and -time were accurately controlled in the system. When activated blood by either shear or agonists in a sample chamber was released to the closure area, activated platelets were adhered and aggregated on the closure area, which is eventually blocked. The characteristic of platelet function is to represent with the migration distance (MD) of blood through microscale circular tube. Comparing with similar devices such as PFA-200 and VerifyNow, the present method and device showed an excellent agreement with them.