MICROFLUIDIC VISCOMETER BY ACOUSTIC STREAMING TRANSDUCERS

Ruoyu Jiang[1,2], Abhinand M. Sudarshana[1,2], Paul Yoo[1,2], , Francesco Palomba[1,2], Michelle Digman[1,2], Abraham P. Lee[1,2]

[1]University of California, Irvine

[2]Center for Advanced Design & Manufacturing of Integrated Microfluidics (CADMIM), University of California Irvine, Irvine

ABSTRACT

The measurement of fluids viscosity represents a huge need for many biomedical and material applications. Sample fluids containing DNA, antibodies, proteins, and even cells have become important therapeutical options. The physical properties, including viscosity, of these biologics are critical factors in the optimization of the biomanufacturing processes. Here we demonstrate an acoustic microstreaming platform that induces fluid transport from second-order microstreaming. We validate our platform with water-glycerol mixture to reflect different viscosities and measure the maximum speed of the second-order acoustic microstreaming within seconds. Our demonstrated platform does not require external instruments to pump fluids and consumes small amount of fluid sample (< 10 μL) and is easy to incorporate with automation systems.

KEYWORDS: Viscosity, Drug Development, Acoustic Fluidic Dynamics

INTRODUCTION

The preparation and processing of biological materials requires a series of complicated purification and tedious enrichment steps. During each step, it is critical to measure the viscosity of sample fluids to screen fluids properties and develop functional materials. The most common viscometer in the lab is the falling cylinder viscometer and there are also microfluidic viscometers [1], [2]. However, all of these methods require either a very precise external pump or a larger volume (>500μL). Furthermore, the setup is more extensive and not amenable to the typical biological researcher. A compact device that is easy to operate and interpret, would be beneficial to the materials and healthcare field.

EXPERIMENTAL

We developed a 16 well array of microviscometers based on lateral cavity acoustic transducers (LCATs) that induced microstreaming vortices as the basis of viscosity measurement elements (Fig. 1A, 1B). The microstreaming velocity will be a function of the sample viscosity given an acoustic actuation frequency and amplitude. We also validated our acoustic microstreaming with particle image velocimetry. Each well accommodated approximately 1.2 μL of the sample fluids. An array of wells is patterned with multiple slanted side channels. The microstreaming pattern is a function of viscosity as the higher the viscosity, the slower the streaming velocity.

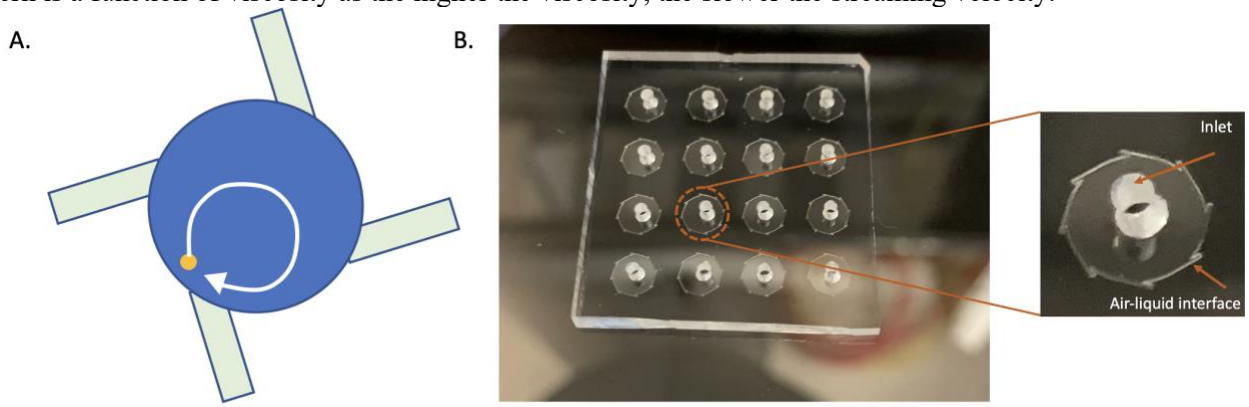

Figure 1. Device Schematics. A. Overview of microviscometer design. Lateral side channels trap air to form microbubble to generate second-order microstreaming and the speed of the microstreaming is a function of viscosity. B. Real image of the microfluidic device.

RESULTS AND DISCUSSION

It was observed that the maximum second-order acoustic microstreaming speed occurred at the air-liquid interfaces (Fig. 2A, B). The speed of the acoustic microstreaming tended to decrease when the beads were moving further away from the air-liquid interface. The maximum speed decreased as the viscosity of the water-glycerol increased from 1 cP to 22 cP under applied input voltage from 4 V_{pp} to 12 V_{pp} (Fig. 2C). Furthermore, as the input voltage increased, the maximum speed of the acoustic microstreaming also increased, suggesting the device can be tested under multiple conditions. We also characterize sample fluids with the use of the 6-acetyl-2-dimethylaminonaphthalene (ACDAN) molecules and observed emission shift for proteins under different viscosities (Fig. 2D). Such measurement can be used to distinguish low viscosity values with high accuracy.

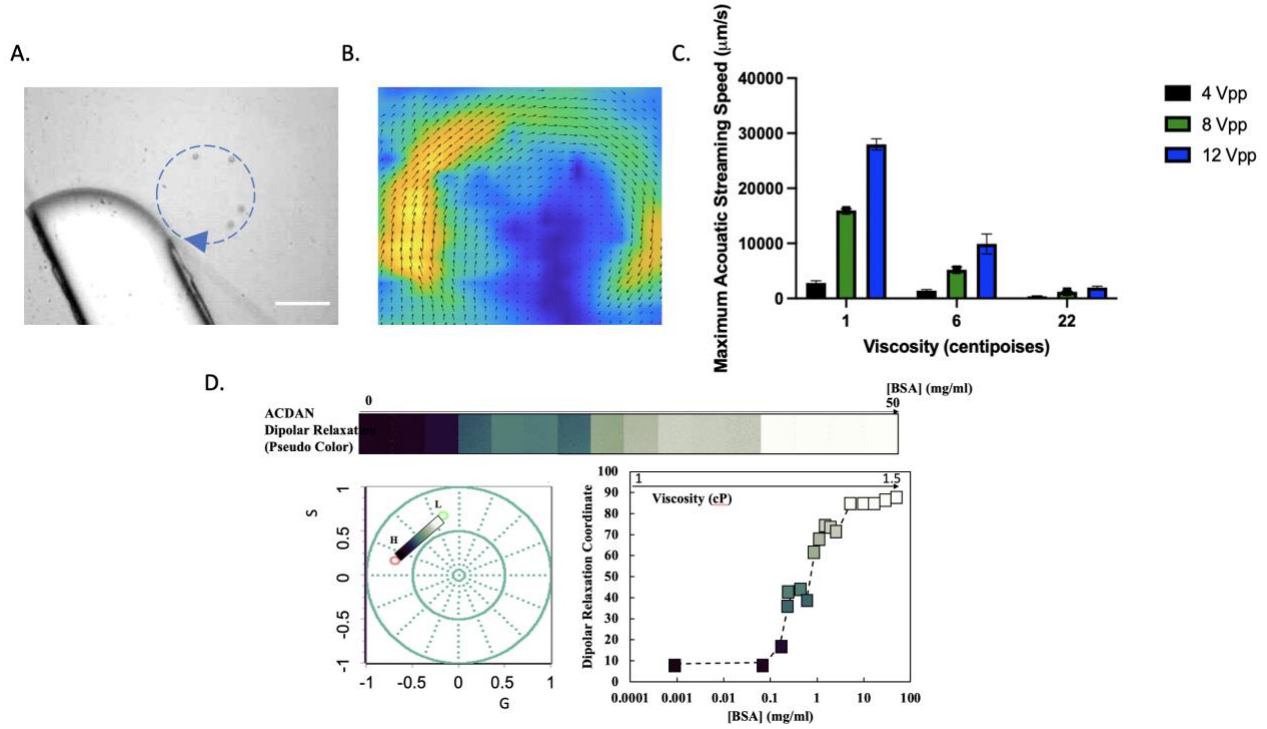

Figure 2. Device Characterization and Sample Calibration. A. Acoustic microstreaming traps bead. Dotted line indicates microstreaming patterns. Scale bar: 50 μm. B. Particle image velocimetry validation of the acoustic microstreaming. C. Sample fluid calibration under different viscosities. D. ACDAN emission shift under different protein concentrations.

CONCLUSION

We have developed an active acoustic microstreaming method to measure the viscosity of complex solutions in the absence of external syringe pump and have demonstrated the potential of this approach by measuring the viscosity of standard water-glycerol mixtures and proteins. Our microfluidic viscometer requires low quantities of sample material (< 2 μL) and operates within 1-2 seconds. Finally, the method is easy to operate and has the feature of automation and is an attractive approach to rapidly measure viscosity with very few samples volume.

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CONTACT

* A. P. Lee; phone: +1- (949) 824-9691; aplee@uci.edu