PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Viscoelasticity measurement comparison between microelastography and surface fluctuations

Pol GRASLAND-MONGRAIN[1], Stefan CATHELINE[2], Ali ZORGANI[2], Damien GARCIA[3], Ludovic BELLON[1], Thomas GIBAUD[1], Sébastien MANNEVILLE[1]

[1] Laboratoire de Physique, Ecole Normale Supérieure de Lyon, Lyon, FRANCE

[2] LabTAU, INSERM u1032, University of Lyon, Lyon, FRANCE;

[3] Creatis, Université Claude Bernard Lyon 1, University of Lyon, Lyon, FRANCE;

ABSTRACT

Microelastography is a recent technique used to measure viscoelasticity of small objects at the micrometer scale, such as biological cell. However, its results have not been compared to other viscoelasticity measurements techniques at this scale.

We propose here to compare viscoelasticity results of microelastography with another based on surface fluctuations. Results show a good agreement between both techniques over a large band of frequencies.

Keywords: Elastography, Shear Wave, Viscoelasticity

1. Introduction

Microelastography is a recent technique used to measure viscoelasticity of small objects at the micrometer scale, such as biological cell. It consists in inducing a shear wave propagation in an object to map the object viscoelasticity. A recent work has applied the technique on a mouse oocyte, with a micropipette inducing a 15 kHz shear wave, and the oocyte was observed with a 200.000 fps camera through a microscope. However, this technique lacks of gold standard due to the high frequency of vibration.

In the other hand, another work has been able to measure sample viscoelasticity at a wide range of frequencies by observing at surface fluctuations.

The objective was to compare both techniques on the same viscoelastic medium.

2. Materials and methods

Both techniques have been tested on a gel sample. The gel was an acrylate sample (Gel coiffant, Casino, France) filled with 5 um microbeads (TS10 Dynoseeds, Microbeads, Norway) at 1% concentration, and degassed during 10 minutes. Both experiments were done during the same day to avoid changes of viscoelasticity over time, with a similar environment temperature (20-22 °C).

For the microelastography experiment, to induce the shear wave in the sample, we used a 30 um diameter pipette (MPH-MED-30, Origio, Denmark) with a piezoelectric actuator (PPA4-M, Cedrat Technologies, France). The system was driven by function generator (HP33120, Agilent, USA) which emitted a 1 V signal with 5 sinusoids of a given frequency, and a repetition frequency of 50 Hz. The frequency varied from 100 Hz to 5000 Hz with a logarithmic spacing.

A high speed camera (v2512, Vision Research, NJ, USA) imaged the sample when vibration were induced in the gel. Displacement was computed with an optical flow technique. Elasticity reconstructed with passive elastography.

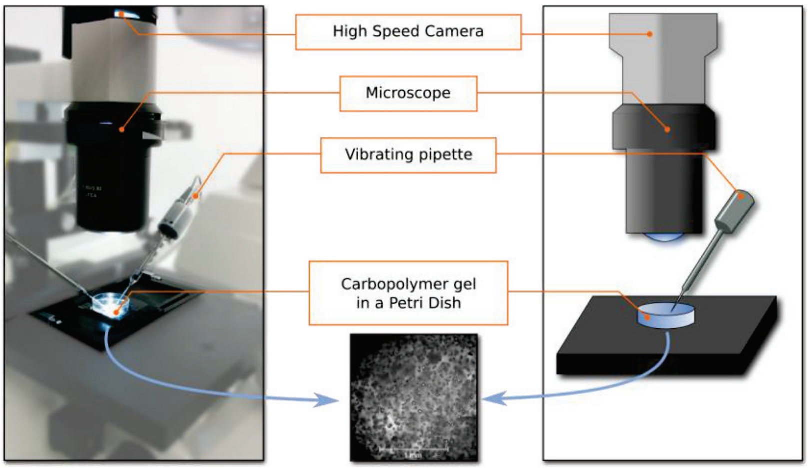

Figure 1. Microelastography technique illustration

Free surface thermal fluctuation setup was built using a 632 nm laser focused on the sample surface. Reflected laser deviations were measured with a four quadrants photodiode. It uses a viscoelastic model with a density ρ = 1000 kg, a surface tension γ = 130 mN/m, an initial elastic modulus G (f = 0 Hz) = 100 Pa, a viscosity η = 0.02 Pa.s and a temperature T = 293 K. Surface fluctuations among a band of frequency of 10 Hz to 100 kHz has been measured, giving the real and imaginary part of the viscoelastic modulus.

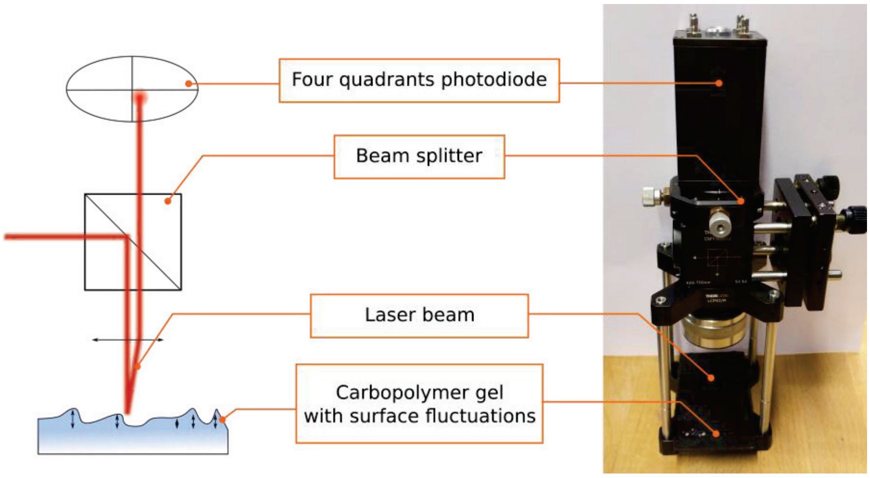

Figure 2. Free surface fluctuation technique illustration

3. Results and discussions

Microelastography provides 2D images of the elasticity, while free surface fluctuations measures viscoelasticity only in one point.

The Figure 3 depicts the shear wave speed of the bulk measured by the microelastography at 500 Hz. Only the right part of the bulk was mapped, as shear waves didn't reach the left side of the sample. The upper and lower left corner are due to a small optical artifact of the initial image. The average value on the right side of the sample is 0.96 ± .05 m/s. With a sample density of 1000 kg/m^3, this corresponds to an elasticity G* of 920 ± 100 Pa.

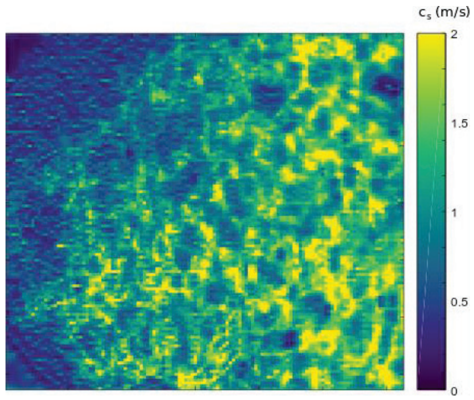

Figure 3. Shear wave speed at 500 Hz as given by microelastography technique

Free surface fluctuations and mean value of the microelastography technique results have been plotted on Figure 4. Free surface fluctuations technique provides both the elastic and viscous part (G' and G''), but for comparison with microelastography technique, only G* have been provided from these two values.

We can observe that although there is some difference above 1 kHz, both techniques measured the same order of magnitude and depicted the same rheological behavior (increase of elasticity with frequency).

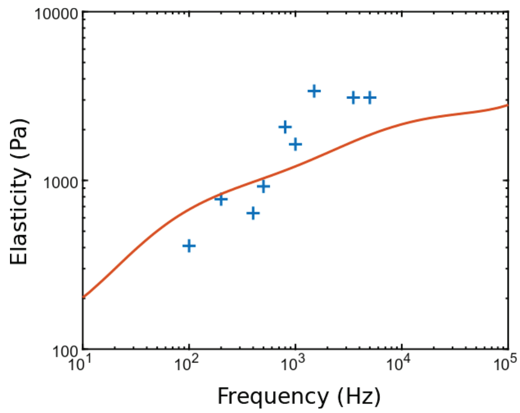

Figure 4. Viscolelastic measurement of the gel sample along frequency measured by the free surface fluctuation technique (red curve) and the microelastography technique (blue cross)

We suppose the differences are due to viscoelasticity variation between surface and bulk of the medium. We plan to get measurements over a wider range of frequencies to get

Also note that the two techniques have different requirements, so cannot be applied simultaneously for any materials: the first has to track shear waves, so a high viscosity may prevent to measure anything far from the vibration source; the second needs a specular surface to reflect the laser beam.

Acknowledgements

This work was supported by a postdoctoral fellowship award from the Fondation pour la Recherche Médicale (PGM).

References

1. Gallot, Thomas, Stefan Catheline, Philippe Roux, Javier Brum, Nicolas Benech, and Carlos Negreira. "Passive elastography: shear-wave tomography from physiological-noise correlation in soft tissues." IEEE transactions on ultrasonics, ferroelectrics, and frequency control 58, no. 6 (2011): 1122-1126.
2. Catheline, S., R. Souchon, M. Rupin, J. Brum, A. H. Dinh, and J-Y. Chapelon. "Tomography from diffuse waves: Passive shear wave imaging using low frame rate scanners." Applied Physics Letters 103, no. 1 (2013): 014101.

3. Grasland-Mongrain, Pol, Ali Zorgani, Shoma Nakagawa, Simon Bernard, Lia Gomes Paim, Greg Fitzharris, Stefan Catheline, and Guy Cloutier. "Ultrafast imaging of cell elasticity with optical microelastography." Proceedings of the National Academy of Sciences 115, no. 5 (2018): 861-866.
4. Pottier, Basile. "Les fluctuations de surface pour mesurer les propriétés de systèmes complexes en l'absence de sollicitation." PhD diss., Université Pierre et Marie Curie-Paris VI, 2013.
5. Pottier, Basile, and Ludovic Bellon. "“Noiseless” thermal noise measurement of atomic force microscopy cantilevers." Applied Physics Letters 110, no. 9 (2017): 094105.