Mechanical Vibrations of Ultrathin Freestanding Polymer Films

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Piezolectric excitation and acoustic detection of the vibrations of ultrathin (30nm-300nm) freestanding polymer films was used to probe their physical properties. A simple method involving acoustic detection of the vibrational response of the films with an inexpensive microphone revealed that the resonant peaks of the films were in the kHz range. Polymer solutions were spin coated onto glass slides to create ultrathin films. These films were released from the slides by floating on to a water surface [1] before being picked up on inexpensive piezoelectric buzzers that had had been prepared with holes in the centre. This created a freestanding membrane whose vibrations could be driven by electrically exciting the piezo. The samples were annealed and quenched to room temperature before measurements were performed. A software-controlled waveform generator was used to drive the piezo and the response of the film was recorded with a microphone (figure 1). Two methods were employed to obtain a spectrum. The first method involved measuring the root mean square microphone signal as a function of the driving frequency. Alternatively, the sample was driven with a large impulse (10Vpp, 100µs in width) and the Fourier transform of the microphone signal was obtained. Both techniques gave identical results for the frequencies of the vibrational peaks which were used to extract information about the mechanical response of the ultrathin films. This approach was previously verified using thick Polydimethylsiloxane membranes [2]. In the current work, the temperature dependence of the frequency of the first mode of vibration of ultrathin poly(tert-butyl methacrylate) and polystyrene films were measured. These data were shown to have a strong dependence on film thickness, providing insights into how molecular confinement effects influence the thermal expansion properties and tension in ultrathin spincast polymer films.

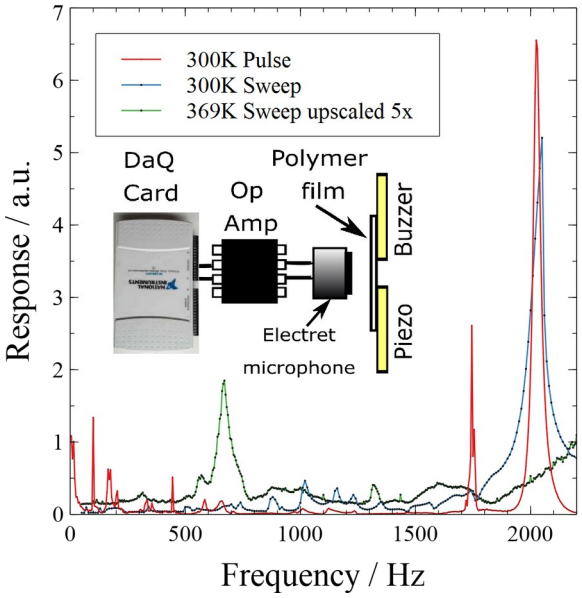

Figure 1. Three spectra generated from an 87nm polystyrene film freestanding over a circular area at two temperatures. At 300K the first mode appears at 2040Hz (blue and red) and at 369K the same mode appears at 670Hz (green) while the film is 10K away from bulk T_g. Inset is a schematic of the electronics that recorded sound generated by the film.

References

[1] Baxamusa, S.H., Stadermann, M., Aracne-Ruddle, C., Nelson, A.J., Chea, M., Li, S., Youngblood, K. and Suratwala, T.I. Enhanced delamination of ultrathin free-standing polymer films via self-limiting surface modification. *Langmuir* **2014**, *30*(18), 5126-5132.

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