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Pressure-dependent Fluidic Dissipation Effect at Multiple Harmonic Cantilever Resonant Modes

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Miniaturized mechanical systems such as nanoelectromechanical systems (NEMS) and microfabricated cantilevers have been regaining much attention along with the advances in fabrication techniques [1,2]. They posses much improved mechanical properties, such as high resonance frequencies and quality factors in their resonant mode, compared to previously-studied mechanical systems. Based on these superior mechanical characteristics, these miniaturized systems have been proven to be promising in many of technological applications. In these, to achieve the optimized operation under various conditions, one needs to carefully assess the dissipation present in the system. For example, when one uses the mechanical sensing element, the detection sensitivity is closely related to quality factor of the mechanical system [3].

Under moderate vacuum, the damping of these mechanical systems is dominated by the intrinsic dissipation and the interaction with the flow can be understood with the Newtonian approach. However, with increase in flow the fluidic dissipation will increase and the Newtonian approximation is expected to be no longer valid. Recently, this break-down of the Newtonian approximation of the fluidic dissipation coupled with the mechanical motion has been considered, where the fluidic dissipation factor has been given as a function of the resonance frequency of the mechanical system and the relaxation time of the fluid [4]. Experimentally this dissipation effect in non-Newtonian limit has been also investigated using doubly-clamped beams and cantilevers, mostly operating in their fundamental resonant modes [5,6].

Here, we will present an investigation of the dissipation effect of a cantilever in motion under various pressures. The changes in the quality factor due to the fluidic dissipation as a function of pressure have been measured between 100 mTorr and 1000 Torr up to third harmonic of its resonant mode. The experimentally observed fluidic quality factors in multiple harmonic modes will be discussed with a flow dissipation model in non-Newtonian limit.

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