Nano-scale sensors for wall-shear-stress measurements

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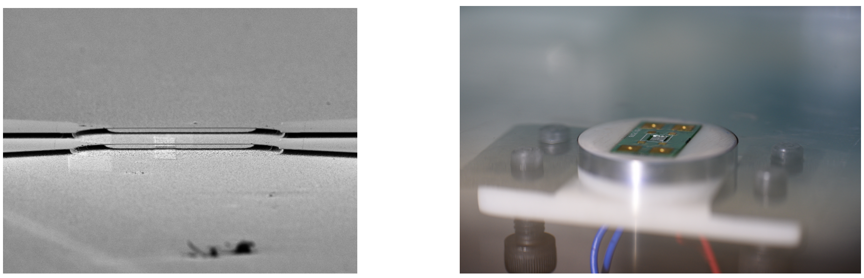
Wall-bounded turbulent flows typically contain a wide range of spatio-temporal scales. Experimental measurements that fully resolve all the scales are of great value in understanding and modeling the underlying flow physics. In a boundary layer flow, wall-shear stress is a physical quantity of fundamental importance, which is not amenable to easy measurements. The present effort is aimed at the development of a novel nano-scale sensor for time-resolved wall-shear-stress measurements in a turbulent boundary layer flow. The sensor is based on the principles of thermal anemometry.[1] These sensors are designed and fabricated in-house using standard nano-fabrication techniques[2] and tested in a low-speed turbulent boundary layer flow. The sensing element is a thin platinum wire of dimension 45 μm x 1.5 μm x 130 nm, with electrical contact pads of dimension 100 μm x 100 μm deposited on a SiO_2/Si substrate. Figure 1(a) shows a scanning electron microscope image (SEM) of the sensor with two independent filaments. The sensor is placed flush with the wall (see figure 1(b)), and is electrically heated (similar to a hot wire probe). Convective transfer of the ohmic heat to the flow informs the local wall-shear-stress condition. Quantitative inference of wall-shear stress requires a calibration exercise, for which a standard acoustic plane-wave tube is employed.[3] Details of the sensor design and fabrication, along with experimental results from a $Re_\tau = 800$ (friction Reynolds number) boundary layer flow will be presented at the conference.



(a) (b)

Figure 1: (a) A representative SEM image of the sensor; (b) Packaged sensor integrated on a flat plate wind tunnel model for boundary layer studies.

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[1]H. H. Bruun, *Hot-wire Anemometry*, Oxford University Press (1995)
[2]Vallikivi and Smits, *IEEE Journal of Microelectromechanical Systems*, **vol. 23**, no. 4 (2014)
[3]Sheplak et al., *AIAA Journal*, **vol. 39**, no. 5 (2001)