Photothermal MEMS-based Chemical Sensors

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Despite years of research, chemical and biological sensors based on Micro-Electro-Mechanical Systems (MEMS) still remain as a laboratory platform because of the unacceptable rate of sensor-to-sensor irreproducibility. Resonant optical excitation of targeted adsorbate molecules on MEMS sensors offers a receptor-free approach for achieving chemical selectivity. Although spectroscopic techniques are routinely used for chemical and biological sensing, obtaining high sensitivity and selectivity requires complex and bulky equipment. However, non-radiative relaxation of resonantly excited molecules, that can generate extremely small amounts of heat by photothermal effect, can be detected using microfabricated cantilevers. Cantilevers, when fabricated as bi-material beams, have a thermal sensitivity in the millikelvin range at ambient temperatures. In addition to photothermal signatures of adsorbed molecules, micromechanical resonators can also provide adsorbed mass and adsorption energy with a very high sensitivity. These cantilever resonators can also be fabricated as microfluidic channels for characterizing confined or flowing liquid samples in them. This approach provides a label-free and receptor-free method for molecular recognition, and overcomes many of the selectivity challenges encountered when using receptor-based approaches. Understanding energy dissipation at resonance can impart additional information for enhancing the selectivity. Multi-modal, multi-physics data obtained with the nanomechanical platform, when analyzed using deep learning techniques, can enhance the selectivity, sensitivity, and reliability even in complex mixtures and environments. I will discuss examples of the detection of drugs, interaction of drugs with drug-resistant bacteria and the unravelling of DNA, etc. in this presentation.