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MEMS for in-situ TEM nanoscience on dry and wet samples

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Abstract:
The combinaison of MEMS and in-situ Transmission Electron Microscopy offers unprecedented insights on atomic or nanoscale phenomena occurring in dry and more recently in wet environments. MEMS overcomes technical challenges in integrating mechanical elements into the tiny space of TEM holder, adding versatility, high integration level, and low cost. Several examples of MEMS in TEM studies are presented. Using a pair of electrostatic actuators, silicon opposing tips within a nanogap can be actuated until the contact, and we observed in real-time the elongation of nanojunction for different materials including Si, Au, Pt, Ag. Additional integration of double actuators allows sliding capabilities for studying nanoscale friction in single Ag nanojunction. Nanoscale heat transfer through a few silicon atoms was also achieved by integrating micro-resistances on the generic MEMS device. A prototype of cryogenic TEM holder was developed with Hitachi and Gatan to operate MEMS from 90K to 360K, and tested to evaluate heat transfer through a diamond-like carbon nanowire made by FIB-CVD method. The field of MEMS in TEM expanded a lot with the capability to encapsulate liquids between electron transparent windows, also called TEM liquid-cell. We present real-time video of nanoscale Au electroplating, as well as a new liquid-cell concept for merging droplets for applications in chemistry, catalysis, and biochemistry.

Keywords: MEMS, in-situ TEM, nanojunction, elongation, friction, heat transfer, DLC-nanowire, cryogenic TEM holder, liquid-cell TEM.