Design of PiezoMEMS for High Strain Rate Nanomechanical Experiments

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Nanomechanical experiments on 1-D and 2-D materials are typically conducted at quasi-static strain rates of 10(-4)/s, while their analysis using molecular dynamic (MD) simulations are conducted at ultra-high strain rates of 10(6)/s and above. This large order of magnitude difference in the strain rates prevents a direct one-on-one comparison between experiments and simulations. In order to close this gap in strain rates, nanoscale actuation/sensing options were explored to increase the experimental strain rates. Using a combination of COMSOL multiphysics finite element simulations and experiments, it is shown that thermal actuation, which uses structural expansion due to Joule heating, is capable of executing uniaxial nanomechanical testing up to a strain rate of 10(0)/s. The limitation arises from system inertia and thermal transients. In contrast, piezoelectric actuation can respond in the GHz frequency range. However, given that the piezoelectric displacement is limited in range, a sagittal displacement amplification scheme is examined in the actuator design, which imposes a lower frequency limit for operation. Through a combination of analytical calculations and COMSOL dynamic analysis, it is shown that a piezoelectric actuator along with a displacement amplifier is capable of achieving ultra-high strain rates of similar to 10(6)/s during nanomechanical testing.