IN-SITU MICROCOMPRESSION HIGH CYCLE FATIGUE TESTS: UP TO 1KHZ FREQUENCIES AND 10 MILLION OSCILLATION CYCLES

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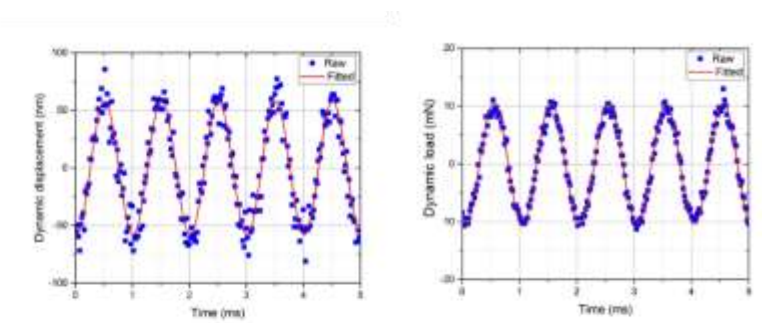
Nanomechanical tests are moving beyond hardness and modulus to encompass host of different mechanical properties like strain rate sensitivity [1,2], stress relaxation [3], creep and fracture toughness by taking advantage of focused ion beam milled geometries and well known stress state during testing. Adding high cycle fatigue (HCF) properties to this list will be useful to extend the gamut of properties studied at the micro/nanoscale. There have been several reports of repeated impact and sinus mode (also referred to as “continuous stiffness mode”) nanoindentation tests for studying the contact fatigue properties of films and coatings. Though promising for studying contact fatigue properties, these measurements suffer from low oscillation frequencies (less than ~ 50 Hz) and, consequently, long duration tests. Merle et al. [4] reported micropillar compression-compression fatigue tests on nanocrystalline Cu at 40Hz and required ~ 7 hours to reach 1 million cycles. For a technique like nanoindentation that typically comprises of thermal drift rates of ~ 3nm/min at room temperature, this amounts to a total displacement drift of 1.2µm over the entire duration of the test (7 hours). Therefore, pushing the frequencies of sinus oscillation tests higher seems to be the key towards minimizing artefacts of measurements and to reach high cycle contact fatigue regime in shorter time spans.

This presentation will report the development of micropillar HCF tests with oscillation frequencies up to 1kHz and compression-compression fatigue tests up to 10 million cycles. Micropillar HCF tests performed on single crystal silicon (reference sample, does not exhibit fatigue at high frequencies) showed no change in unloading stiffness over 10 million cycles, suggesting the reliability of the developed experimental technique. The associated instrumentation and technique development, design of the fatigue tests at the micron scale, data analysis methodology, experimental protocol and challenges will be discussed. Compression-compression high cycle micropillar fatigue of nanocrystalline nickel will be presented and the experimental results will be discussed in light of existing literature data, particularly the operative deformation mechanism(s). The fatigue tests were performed both below and above the 0.2% offset yield strength. Prolonged fatigue tests resulted in grain growth and microstructural changes in nanocrystalline nickel. The associated changes in mechanical deformation data (unloading stiffness, load and displacement amplitudes) will be discussed. The convolution of time dependent plasticity in such tests will be addressed by comparing both load and displacement controlled fatigue tests at high frequencies. It is hoped that this study will pave way for routine high cycle fatigue tests of metals at the micron scale and provide clues for designing similar indentation based fatigue tests.



Quality of displacement and load raw data obtained at 1kHz sinus frequency tests on Si micropillars

[1] J. Wehrs, G. Mohanty, G. Guillonneau, A.A. Taylor, X. Maeder, D. Frey, L. Philippe, S. Mischler, J.M. Wheeler, and J. Michler, JOM 67, 1684 (2015).
[2] G. Mohanty, J.M. Wheeler, R. Raghavan, J. Wehrs, M. Hasegawa, S. Mischler, L. Philippe, and J. Michler, Philos. Mag. 95, 1878 (2015).
[3] G. Mohanty, J. Wehrs, B.L. Boyce, A. Taylor, M. Hasegawa, L. Philippe, and J. Michler, J. Mater. Res. 31, 1085 (2016).
[4] B. Merle and H.W. Höppel, Exp. Mech. 58, 465 (2018).