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Title: Recent Results in Dynamic Compression of Diamond Anvil Cells with Piezoelectric Actuators

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The recently developed dynamic Diamond Anvil Cell (dDAC) has provided a new tool to study materials at strain rates between traditional diamond anvil cell and shock experiments. In a dDAC, the mechanical force to compress the diamonds is provided by a piezoelectric element (“stack”), allowing for a faster and more controllable compression than is achievable by mechanically turning screws or with gas membrane compression. Piezoelectric driven DACs (dDAC) were first reported in 2007 (1) with subsequent developments (2) and multiple experiments since then (3). Dynamically driven diamond anvil cells, together with advances in synchrotron X-ray facilities, have provided opportunities for time-resolved DAC experiments. With controlled strain rates ($d\varepsilon/dt$) between 10^{-1} s^{-1} and 10^{2} s^{-1}, dynamic DAC experiments provide insight into phase change kinetics, texturing, deformation mechanism, phase persistence, etc., as a function of strain rate. In order to understand the sample pressure response in the DAC by the force provided by the piezoelectric stack, it is important to determine the relation between compression characteristics in the DAC assembly and piezoelectric stack. The sample pressure in the DAC depends on multiple factors, including: anvil culet size, gasket properties (thickness, material, hole size), the presence or lack of a pressure transmitting medium, and initial pressure among others. Recent experiments at LANL have focused on systematically exploring these factors and their relative effect on sample pressure in order to develop a predictive relationship between applied voltage to piezoelectric stack and resulting change in sample pressure. Initial test measurements were performed on gold and zirconium samples. Gold provides a nice baseline due to its well-known structural stability over broad P-T range. Zirconium (Zr) on the other hand has a well-known hexagonal (ω) ↔ body centered cubic (β) phase transition ~30 GPa. Zr experiments were performed at three different compression rates, 20 GPa/s, 40 GPa/s, and 80 GPa/s, with time resolutions of 40 ms, 20 ms, and 10 ms, respectively. In each case, the experiment started with an initial pressure around 15 -20 GPa and reached final pressures of ~55-60 GPa. A 1000 V step function applied to the piezoelectric stack led to a 3% strain in gold between successive diffraction images at a 10 ms interval. This result provides a lower limit of 3 s^{-1} on the strain rate achievable with this setup, necessitating the need for better time resolution. Better time resolution requires faster X-ray detectors and potentially higher X-ray flux. Experiments planned for summer 2019 will utilize detectors with kHz sampling rates, allowing for faster time resolved experiments.

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3. Dane Tomasino, and Choong-Shik Yoo, “Solidification and crystal growth of highly compressed hydrogen and deuterium: Time resolved study under ramp compression in dynamic-diamond anvil cell”, *Applied Physics Letters*, **103**, (2013)