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An Attempt of Equation of State Measurements for Pressure Standard Materials Using Laser-Driven Ramp-Wave-Compression

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Static compression methods such as diamond anvil cell and multi anvil apparatus are widely used in high-pressure sciences including earth, planetary and material sciences. Pressure in static compression is calibrated using empirical equation of states (EOS) for so-called pressure standard materials based on dynamic shock compression data. However, an inconsistency between several pressure scales has been argued as a significant problem particularly in the Earth sciences.

One of dominant contributions to the pressure scales uncertainty is the uncertainty of the Gruneisen parameter volume dependency. The Gruneisen parameter is used to reduce the shock Hugoniot data to P-V-T surface, calculating the thermal pressure, which caused by thermal energy. In this procedure, higher temperature has more negative effect on accuracy of the reduced low temperature isotherm. High pressure and relatively low temperature ramp-compression (or quasi-isentropic compression) P-V-E data can be used not only to obtain precise low temperature isotherm but also as a constrain condition to determine all over P-V-T surface.

In this study, we have proposed to study EOSs of the pressure standard materials using ramp-wave-compression technique as a novel approach different from shock compression. Laser-driven ramp-wave-compression (RWC) technique was used to shocklessly (or quasi-isentropically) compress platinum sample up to a peak longitudinal stress of 40 GPa. Platinum stress-density data along the ramp-compression path was determined up to 20 GPa from free-surface velocity data of different thickness samples.

The experiments were conducted on the LULI2000 laser facility in the Laboratoire pour lUtilisation des Lasers Intenses (LULI), Ecole Polytechnique. The laser-driven ramp-compression target consists of a 75 um polyimide foil as a reservoir which is a source of expansion plasma, a 20 0 um vacuum gap, and the 10 or 24 um Pt target with a purity of better than 99.98 %. A spatially smoothed laser beam was focused onto the polyimide foil with a 1 mm spot diameter, 4 ns pulse duration, a wavelength of 527 nm, and 378 or 374 J pulse energy. A strong laser-driven shock wave is used to pressurize the polyimide and turn it into weakly ionized plasma. After shock breakout from the rear surface, the polyimide rarefies across the vacuum gap and a smooth momentum gradient of the polyimide plasma is generated. This plasma with momentum gradient loads up against the platinum sample, and launches a ramp compression wave into it. As the compression wave reached the rear surface of the platinum, it begins to accelerate into free space. The two line-imaging VISARs were employed to measure the free-surface velocity, ufs, of the platinum.

We estimated from free-surface velocity history deduced from VISAR trace and SESAME EOS that the ramp-compressed platinum reached up to a peak longitudinal stress of 40 GPa. The energies between shots on 10 um and 24 um were very close. We determined lagrangian sound velocity from these different thickness sample data, assuming that equivalent compression waves were generated. The lagrangian analysis method was used to determine the lagrangian sound velocity, CL(up) and stress and density from ufs (t) and up (t) = ufs (t)/2 approximation, where up is the particle velocity. Obtained stress-density data up to 20 GPa is in good agreement with SESAME EOS.

Applying recently developed pulse-shaped-laser-driven RWC technique with improved diagnostics, EOS measurements of pressure standard materials in the multi-Mbar regime with higher accuracy will be potentially realized.

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High-Power Laser