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Spectrally resolved x-ray scattering diagnoses electronic properties of solid density plasmas*

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Experiments on the metallic and insulator behavior of solid density plasmas have been performed with a novel use of spectrally resolved x-ray scattering in isochorically heated carbon plasmas. The x-ray scattering experiments performed and analyzed by plasma physicists from Lawrence Livermore National Laboratory using the Laboratory for Laser Energetics OMEGA laser facility in Rochester, NY (Gianluca Gregori, 925-422-3720 gregori1@llnl.gov) allowed the simultaneous measurements of bound, weakly bound, and free electron fractions from both cold and hot solid density plasmas that are uniformly heated by x-rays to temperatures up to 50 eV. These scattering processes give rise to elastic and inelastic scattering features that are time-resolved with a Bragg crystal spectrometer. From these features a direct measurement of the electron temperatures is obtained by analyzing the broadening of the Compton down-shifted line, and the ionization state is inferred from a detailed fit of the elastic and inelastic scattering features. For this purpose, x-ray scattering theory was modified to include high density plasma effects on both bound and free electrons. A sensitivity analysis indicates that the temperature of the solid density plasma can be measured with an accuracy of 20% and the ionization state can be determined to ~10%. For few eV carbon, the scattered spectra display a momentum distribution of bound electrons indicating insulator properties in contrast to results obtained from beryllium that show metallic-like behavior. Comparing these data to various theoretical physical and chemical picture models provides a direct test of their applicability to solid density plasmas. Such tests are important for the validation of ionization balance theories of solid density plasmas as well as for calculations of macroscopic properties such as the conductivity, opacity, or equation of state, which are of great interest to high energy density physics. The technique has been extended to soft x-ray radiatively heated materials and compared to measurements on cold samples taken at synchrotrons.

G. Gregori, GI1.002

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Figure Caption: Ionization state vs. temperature measured by x-ray scattering and compared to various theories