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Phase Transition Kinetics and High-Rate Stress-Strain Response of Pure Cerium

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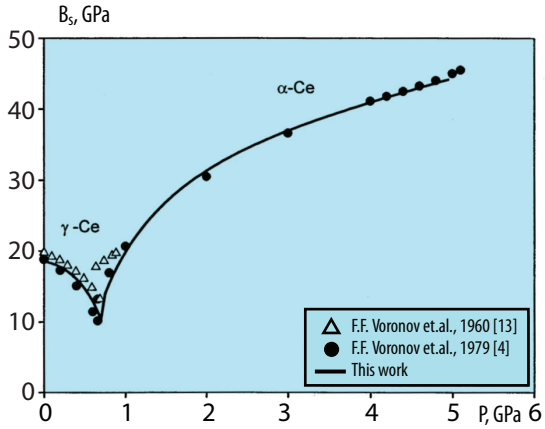
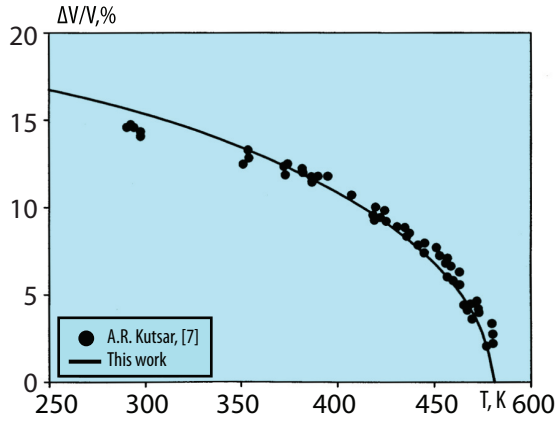
Project Description

Cerium has a very complex phase diagram. There are four solid phases at zero pressure, and at least three additional phases at elevated pressure. The γ phase (the stable room temperature zero pressure phase) exhibits an unusual hydrostatic constitutive behavior wherein the bulk modulus decreases with increasing pressure. Cerium is unique in that it is the only pure element possessing a solid-solid critical point. Perhaps the most interesting feature of cerium is the nature of the α–γ solid-solid phase transition, which occurs at about 0.75 GPa on the room temperature isotherm. This transformation is accompanied by a substantial (almost 15%) reduction in volume. This transition will have a profound effect on the dynamic response of cerium. The very large volume collapse has the effect of causing the temperature to increase at a rate much higher under dynamic compression than would be the case without the volume change. This should cause the pressure on the Hugoniot at which cerium melts to be much lower than that observed for many other metals. Cerium is thus an excellent choice of material for studies of shock-induced melting (and subsequent solidification). The complex phase structure of cerium also makes it an excellent material for studying phase stability and the kinetics of polymorphic phase transition.

A variety of experimental techniques will be used in this study. These include use of the Hopkinson split pressure bar, flyer plate impact, and the optical lever arm technique applied to wedge samples loaded by both sliding and normal detonation of high explosives. Issues to be investigated include phase stability and the kinetics of polymorphic phase transition, shock induced melting (and subsequent solidification), and



Adiabatic bulk modulus versus pressure (preliminary 2-phase EOS) compared to experimental data.

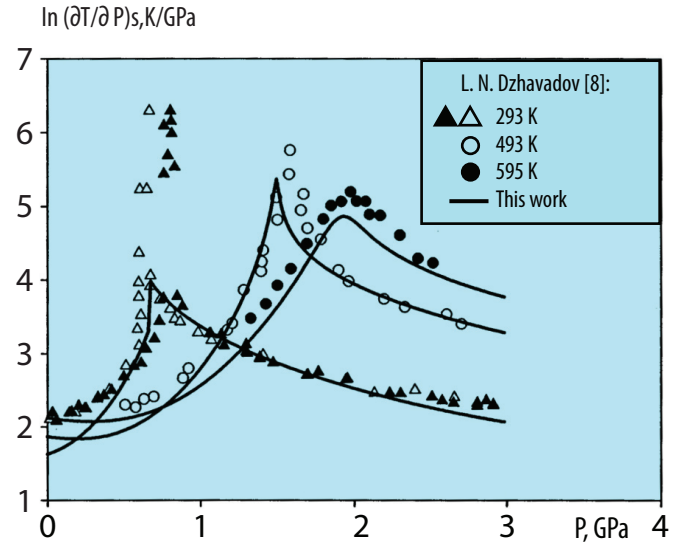


Volume change occurring with γ–α transition versus temperature (preliminary 2-phase EOS) compared to experimental data.

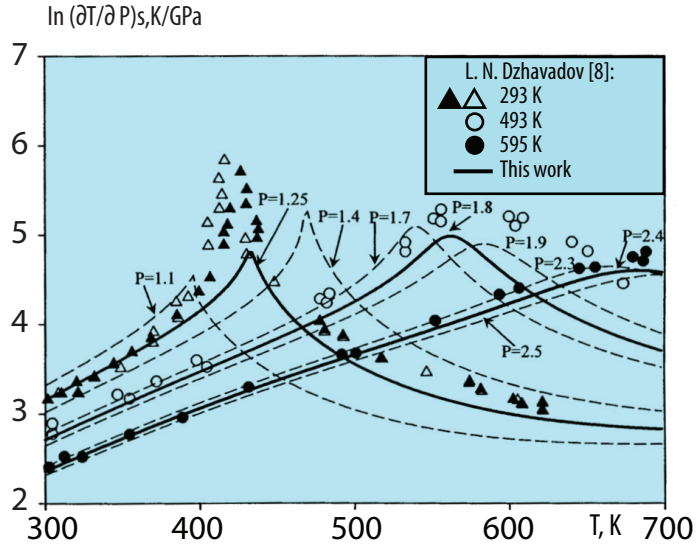
both hydrostatic and deviatoric constitutive behavior. Experimental results will be used in support of the development of a multiphase equation of state (EOS) and of an improved constitutive model for the deviatoric response of cerium.

Technical Purpose and Benefits

The development of better predictive capability is essential if LANL is to meet its obligations to NNSA and the country. One area where much remains to be understood, and where better understanding could be applied to the development of improved predictive capability, has to do with phase stability and the mechanics and kinetics of polymorphic phase transition. This work supports the objectives of the NNSA and both research institutions (LANL and VNIITF) as they endeavor to improve their predictive capabilities with respect to phase stability, polymorphic phase transition kinetics, multiphase equation of state, and deviatoric constitutive response of materials that are complex with respect to phase space.



Log (∂T/∂P)s versus pressure (preliminary 2-phase EOS) compared to experimental data.



Log (∂T/∂P)s versus temperature (preliminary 2-phase EOS) compared to experimental data.

Collaboration between Los Alamos National Laboratory, Los Alamos, NM, USA, and the Russian Federal Nuclear Center – All Russian Research Institute of Technical Physics (RFNC-VNIITF), Snezhinsk, Russia

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