potassium chloride,[16,17] antimony,[18] and Arkansas novaculite.[19] A framework for interpreting experiments in dynamic polymorphism was provided by Horie and Duvall,[20] who combined continuum mechanics and thermodynamics to treat the evolution of shock waves in materials with time-dependent phase transformations.

1.2. Alpha to Epsilon Transformation in Iron

Discovery of and serious attempts to understand the iron transformation appear to have followed the publication by Walsh[21] of high pressure iron Hugoniot data which disagree markedly with existing work on its compressibility at lower pressures. In particular, the results implied compression of iron significantly greater than would be expected from extrapolation of static compressibility data of Bridgman.[1] This stimulated studies using shock waves at lower stresses. The discrepancy in compressibility was resolved by the discovery by Minshall and his coworkers[2,22] of multiple shock stress waves from which they inferred the existence of a polymorphic transformation near 130 kbar.

Many questions still remain unresolved about the pressure-induced iron phase transformation. The mechanism of transformation and effects of shear, temperature, pressure gradients, and strain rate on the transformation process are not fully understood. In addition, Hugoniot data and equilibrium thermodynamic predictions differ for the mixed-phase region. The work in this dissertation is directed toward understanding the non-equilibrium behavior of the mixed-phase region for the iron transformation.

1.2.1. Background

Iron is an elastic-plastic material which undergoes a phase transformation when stressed above 130 kbar. These properties will result in three forward-facing shocks (elastic, plastic I, and plastic II, respectively) traveling away from the impact surface. Under equilibrium conditions the stress behind the plastic I shock is a measure of transformation pressure for the polymorphic transformation. Time-dependence of the transformation requires that stress in the plastic I shock and the plastic II shock overshoot their equilibrium values for short times after impact. The evolution of the shocks is illustrated in Fig. 1.1 where shock wave pressure-distance profiles are drawn for two different times following impact on the left. Measurement of shock amplitudes as a function of thickness can be used in conjunction with appropriate models to obtain information about kinetics of the transformation process.

1.2.2. Shock Profile Data Related to Transformation Kinetics

Transformation rate affects the shapes and amplitudes of shocks in iron. There are four types of existing experimental data on shock profiles in iron which relate to transition kinetics. The four types of data are: (1) amplitude of stress behind the plastic I shock as a function of sample thickness, (2) amplitude of stress behind the plastic I shock as a function of final driving stress for constant sample thickness, (3) rise time in the plastic II shock front, and (4) thickness of the plastic II shock front inferred from residual metallurgical effects.