and Graham and Asay [78G5]. A contemporary summary of studies on other materials is given in table 4.10.

Table 4.10
Investigations of resistance of shock-loaded metals

Metal	Authors	Stress range, GPa	Remarks
Iron	Fuller and Price [62F1]	6 to 37	polymorphic transition
Iron	Wong et al. [68W4]	2 to 18	polymorphic transition
Iron	Royce [68R4], [71R3]		demagnetization currents
Iron	Keeler and Mitchell [69K1]	5 to 37	polymorphic transition
Iron	Keeler [71K2]	5 to 150	very high pressure
Nickel	Wong et al. [68W4]	2 to 14	smooth changes
Copper	Keeler [71K2]	4 to 140	discontinuity at < 140 GPa
Ytterbium	Ginsberg et al. [73G3]	0.1 to 3.3	polymorphic transition, 3.3 GPa
Ytterbium	Murri et al. [74M3]	0.4 to 2.1	
Ytterbium	Grady and Ginsberg [77G3]	0.1 to 0.6	piezoresistive
Ytterbium	Pavlovskii [77P1]	2 to 22	polymorphic transition, 2–3 GPa
Carbon	Horning and Isbel [75H1]	0.4 to 3.4	highly nonlinear behavior
Carbon	Murri et al. [74M3]	0.4 to 1.5	—
Calcium	Murri et al. [74M3]	0.4 to 2.7	—
Lithium	Murri et al. [74M3]	0.4 to 5.4	—
Cadmium	Murri et al. [74M3]	0.4 to 2.8	—
Indium	Murri et al. [74M3]	0.4 to 1.5	—
Lead	Murri et al. [74M3]	1.5 to 1.9	—
Bismuth	Murri et al. [74M3]	1.0 to 1.9	—
Manganin	Fuller and Price [62F1]	6 to 30	first measurements
Manganin	Bernstein and Keough [64B2]	2.4 to 18	
Manganin	Keough and Wong [70K1]	0.6 to 16	various insulators
Manganin	Barsis et al. [70B3]	0.2 to 9	piezoresistive analysis
Manganin	Kanel' et al. [78K2]	2 to 27	residual upon unloading
(For a more complete summary of the various studies on Manganin, see Graham and Asay [78G5] and Murri et al. [74M3].)			
Silver	Dick and Styris [75D1]	2.5 to 12	detailed study

Although the only detailed study is that of Dick and Styris, several general conclusions can be drawn from various other measurements. There is abundant evidence that shock-induced changes in resistance are sensitive to specimen configuration, especially to the host material in which the metallic wire or foil is placed to provide electrical insulation or an approximate mechanical impedance match. This sensitivity apparently results from localized plastic deformation not characteristic of bulk material. The configurational effects can be minimized by careful attention to surface finish, configuration of the metal sample and assembly procedures. Integrity of electrical connections remains a significant consideration but reliable experiments have been reported as high as 140 GPa in copper and iron [71K2].

Following the early observations by Fuller and Price [62F1], a number of investigators measured shock-induced resistance changes in iron (see table 4.10). There is no detailed analysis of these measurements but observed resistances below the transition (corrected for thermal contributions) are substantially different in magnitude and their pressure derivatives are of opposite sign to the static-high-pressure measurements of Balchan and Drickamer [61B1]. Wong et al. [68W4] have interpreted subtle variations in resistance measurements in the vicinity of 7.5 GPa as evidence for a partial transformation below the established 13 GPa transition but, within a reasonable experimental precision, their data can be equally well fit by a continuous change. This later study shows a sharp change in resistance indicative of a phase transition beginning at 12.5 GPa.

The most complete and systematic study has been performed on silver foil by Dick and Styris [75D1] and the results of their investigation are summarized in fig. 4.10. Shock-compression measurements on silver of two different purities are shown by the upper experimental points. Subtraction of the calculated change in resistivity due to shock heating produces the points which represent the resistivity change due to isothermal shock compression. The difference between the isothermal hydrostatic calculations and the isothermal shock results can be accounted for by the shock-induced generation of large numbers of defects, most likely vacancies. Vacancy concentrations, which under these transient conditions also lead to interstitial concentrations, of about 10^{-3} per lattice site, were found to account for the differences between hydrostatic and isothermal shock-compression resistivities.

In an investigation of ytterbium under shock compression, Grady and Ginsberg [77G3] included active measurements of resistance synchronous with shock decompression. Increases in temperature were negligible at their low stresses (< 1 GPa) and the residual resistance served as

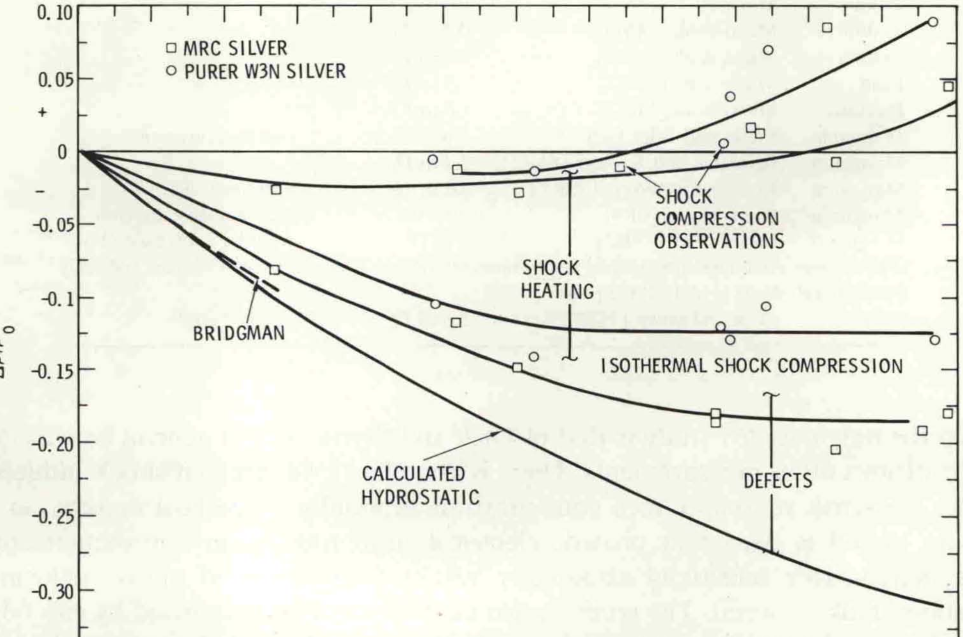

Fig. 4.10. A comprehensive study of silver under shock loading by Dick and Styris [75D1] shows evidence for resistance change due to shock-induced vacancies. The upper group of points are those observed in the shock-loading experiments. The lower group of points results from correcting those data for increases in temperature due to shock heating. The difference between the isothermal shock data and the hydrostatic predictions are evidence for resistivity change due to shock-induced vacancy concentrations of 10^{-3} per lattice site at 10 GPa.