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POINT DEFECT RECOVERY OF SHOCK DEFORMED IRON ALLOYS

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1. Introduction

Recovery phenomena in iron alloys indicate that various measurable properties may recover at different rates[1], [2]. The recovery of electrical resistivity in deformed, quenched and irradiated metals has shown that point defects have been produced. Kressel and Brown[3] have shown that point defects dominate the microstructure of shock deformed nickel. Murr and Vydyanath[4] have attributed thermal recovery of shock loaded 304 stainless steel to the annealing out of point defects. The work of reference (4) employed microhardness measurements to monitor recovery. Previous experimental work[3] has shown that electrical resistivity is sensitive to vacancy and interstitial changes in shocked metals. No experimental results on the recovery of electrical resistivity of shock deformed iron alloys have been published. This paper investigates the nature of defects formed and the recovery of initial flow stress and electrical resistivity in shock deformed iron manganese alloys.

2. Experimental Details

The Iron manganese (Fe-7.37 wt & Mn) specimens were initially annealed at 900°C and furnace cooled. The shock deformation was accomplished in the usual manner[5]. The variation of flow stress with the amount of shock deformation and length of recivery anneal was determined by straining the shocked specimens in a Tinius Olsen machine. The four probe resistivity technique was used to measure resistivity as described elsewhere[3].

3. Experimental Results and Discussion

The results of the recovery experiments are shown in Figure 1. We define the fraction of residual shock hardening as

$$1 - R = \frac{\sigma - \sigma_o}{\sigma_m - \sigma_o} \tag{1}$$

where R is the fraction of recovery, σ the recovery flow stress after anneal, σ_o the flow stress in the fully annealed state, and σ_m is the flow stress of the shock hardened material at a σ_m predetermined strain. The change of residual shock hardening has been shown empirically to be:

$$\frac{d(1-R)}{dt} = a \exp\left(\frac{-b}{a}\right) \exp\left(\frac{1-R}{a}\right)$$

$$= -c \exp\left(\frac{-E}{kT}\right) \tag{2}$$

Consequently we can obtain an activation energy for recovery from the expression:

$$\ln a + \frac{1-R-b}{a} = \ln c - \frac{Eact}{kT} \tag{3}$$

The activation energy at 90 kb at the initial (R=0) stages of recovery was determined to be 22.8 kcal/mole, at 300 kb, the activation energy was 20 kcal/mole and at 500 kb the activation energy was 19.5 kcal/mole. Knowing that the activation energy for migration of vacancies in iron is about 18 kcal/mole, then it is not unreasonable to assume that vacancies alone play a predominant role in the earliest stages of recovery. In the last stages of recovery (R=1) the activation energy was measured to be 75, 90, and 91 kcal/mole at 90, 300 and 500 kb. In the last stages of recivery, it is speculated that dislocation climb may be important since the activation energy for self diffusion in iron is 67 kcal/mole.

Defect concentration estimates from resistivity experiments reqüire the identification of annealing stages. In the present work three anneal stages were observed which are identified as stages III, IV and V. The specimen resistivity after shock deformation is denoted as ρs, then $\rho s - \rho(2.0°C)$ is stage III, $\rho(210) - \rho(450)$ is stage IV and $\rho(450) - \rho(\text{anneal})$ is stage V. Resistivity changes during each stage for the four shocked specimens are shown in Table I. Point defect concentrations were obtained by the same method used by Kressel and Brown[3].