

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

$$1 - R = \frac{\sigma - \sigma_0}{\sigma_m - \sigma_0} \quad (1)$$

where R is the fraction of recovery, σ the recovery flow stress after anneal, σ_0 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:

$$\begin{aligned} \frac{d(1-R)}{dt} &= a \exp\left(\frac{-b}{a}\right) \exp\left(\frac{1-R}{a}\right) \\ &= -c \exp\left(\frac{-E}{kT}\right) \end{aligned} \quad (2)$$

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

$$\ln a + \frac{1-R-b}{a} = \ln c - \frac{E_{act}}{kT} \quad (3)$$

The activation energy at 90 kb at the initial (R=0) stages of recovery was determined to be 22.3 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 recovery, 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 require 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 ρ_s , then $\rho_s - \rho(2.0^\circ\text{C})$ 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⁾.

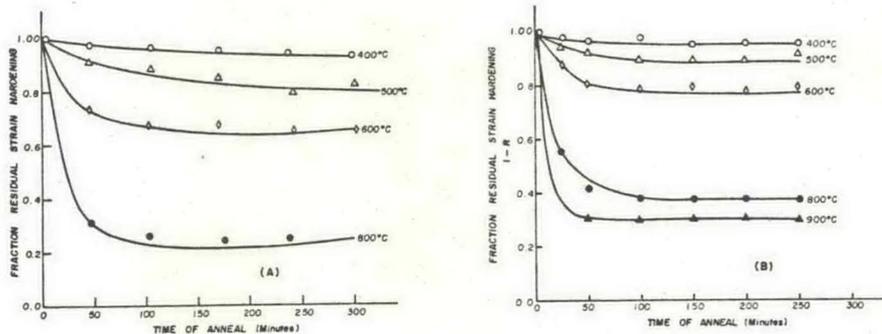


Figure 1 Isothermal recovery curves for shock deformed Fe-Mn, (a) 90 kb (b) 300 kb,

TABLE I

Resistivity Changes and Estimated Point Defect Concentrations

P (kb)	$\Delta\rho_{III}(\mu\Omega\text{-cm})$	$\Delta\rho_{IV}(\mu\Omega\text{-cm})$	$\Delta\rho_V(\mu\Omega\text{-cm})$
90	0.78×10^{-2}	0.85×10^{-2}	1.62×10^{-2}
150	0.85×10^{-2}	0.91×10^{-2}	2.50×10^{-2}
300	0.97×10^{-2}	0.92×10^{-2}	2.90×10^{-2}
500	1.15×10^{-2}	1.05×10^{-2}	2.98×10^{-2}

P	$C_i(\text{Interstitials})$	$C_v(\text{Vacancy})$	$C_d(\text{Dislocations})$
90	$.78 \times 10^{-5}$	2.91×10^{-5}	1.54×10^{10}
150	$.85 \times 10^{-5}$	3.13×10^{-5}	2.40×10^{10}
300	$.97 \times 10^{-5}$	3.30×10^{-5}	2.78×10^{10}
500	1.15×10^{-5}	3.78×10^{-5}	2.88×10^{10}

Two features of the experimental results should be emphasized: (a) There are approximately seven times more vacancies than interstitials. (b) Both vacancy and dislocation density appear to reach saturation with increasing strain. The resistivity data agrees with the recovery kinetics since it was shown that vacancies alone play a predominant role in the earliest stages of recovery. Stage V recovery requires a higher activation energy since dislocation climb is important.

Based on the experimental findings of this work, the following conclusions have been reached:

(a) The initial stages of annealing after shock deformation are associated with migration of vacancies, while the last stages of recovery are associated with dislocation climb.

(b) Vacancy and dislocation density appear to reach saturation with increasing strain. This saturation can be explained by examining the dominant point defect generation processes.

References

1. W. Carrington, K. F. Hale and D. McLean, Proc. Roy. Soc., A259, 203 (1960).
2. T. P. Wang and N. Brown, Trans ASM, 50, 541 (1958).
3. H. Kressel and N. Brown, J. Appl. Phys., 38, 1618 (1967).
4. L. W. Murr and H. R. Vydyanath, Scripta Met., 4, 183, (1970).
5. G. E. Duval and G. R. Fowles, High Pressure Physics and Chemistry. (Academic Press, New York 1963), Vol. 2, pp 69, 75.
6. J. Friedel, Dislocations (Pergamon Press, New York, 1964).
7. F. Seitz, Adv. Phys. 1, 43 (1952).