Cottrell atmosphere report samples

Health & Medicine, Stress

INTRODUCTION:

The concept of Cottrell atmosphere is important to many aspects of material sciences and engineering. This was first proposed by Cottrell and Bilby in 1949 to explain the interaction of solute carbon atoms with defects in steel. The Cottrell atmospheres occur under the interaction between the dislocations and impurities (alloying elements) in matrix metal. These defects, like a dislocation, produce long-range elastic stress fields that distort the interstitial lattice site around the defect in the matrix. These distorted lattice sites then provide lower energy sites for the solute carbon to occupy, thus relieving some of the stress field. This raises the flow stress for dislocation. Cottrell atmospheres lead to the formation of Luder bands and large forces for deep drawing and forming large sheets. Let’s discuss about the condition of parameters like temperature, interaction energy and diffusivity in formation of Cottrell atmosphere formation in matrix of metallic alloys.

TEMPERATURE

The condition for formation of Cottrell atmosphere is that, temperature is sufficiently high for defect migration to occur. However, this temperature is not high enough for the entropy contribution for free energy to cause the atmosphere to evaporate in the solvent matrix. This can be explained from the following equation.

$c (x, y) = c0 \exp[-E1(x, y)/kT]$

The equation implies that, even in dilute solutions of say, $c0= 0. 001$, dense atmospheres with $c\geq0. 5$ may be expected at $T= 0. 5Tm$ (Tm is the melting point), in regions where –E1≥ 3kTm. This corresponds to a binding energy for defect-dislocation in the order of 0. 2 to 0. 5 e V for metals which is fairly commonplace for interstitial solutes.

High Temperature:

In study involving aluminium alloys used in automotive sectors, it was found that Portevin-LeChatlier (PLC) effect caused by Cottrell atmosphere, showed a reduction in fracture elongation and uniform elongation leading to a decrease in the strain-hardening co-efficient. It implied that, the intensity of Cottrell atmosphere was directly proportional to the quantity of dissolved atoms with sufficiently high diffusivity and time to form Cottrell atmosphere. On the other hand, it was also noticed that, if the temperature is reduced, diffusivity is generally decelerated. With reduced diffusivity of dissolved atoms, formation of Cottrell atmosphere of same intensity at same time period was unlikely. It was also inferred that, as temperature converges to 0K, force required to move a dislocation through the crystal lattice reaches a maximum.

Room Temperature:

Similar to aluminium alloys, there are studies proving increase in hardness of steel. In freshly quenched martensite, carbon will become trapped by defects, such as dislocations, as they form a strain field to which solute like carbon are attracted. Carbon atoms gather in the vicinity of dislocation, thereby forming a Cottrell atmosphere. By introducing an intermediate stage between quenching and tempering of martensite, on ageing at room temperature, thereby controlling carbon segregation in dislocations will show 10% increase in hardness and more stable precipitate structure.

Too Low and Too High Temperature:

At too low temperatures, the solute atoms will not be able to diffuse to dislocations. On the other hand, at too high temperatures (above about half the absolute melting point), the solute atoms tend to become much mobile and become ineffective in pinning dislocations.

In the matrices of metallic alloys of Fe, Cu, Si etc., the probability of occurrence of defect-dislocation interaction, leading to the formation of a new state characterized by reaction energy gain is dependent on temperature. The temperature dependencies for defect-dislocation reaction probability correspond to the point defect concentrations. In order for the defects present in the crystal at a concentration of say 10-6 to getter at the dislocation, the temperature should be above 900 K and interaction energy should exceed 1. 5 e V. Consider a edge dislocation in a body –centered cubic metal like iron. Directly above the dislocation, the compressive stress tends to lower the carbon or nitrogen atom concentration. At the same time, the tensile stress below the dislocation will tend to attract these atoms. The dislocation atmosphere around the edge dislocation will thus have an excess of interstitial atoms below the edge and a deficiency of these atoms above the edge. When such a dislocation moves at a high temperature sufficient enough for the solute atoms to become mobile, the atmosphere also tends to move along with the dislocation. When the dislocation moves away from the atmosphere, creates an effective stress on the solute atoms that attract them back toward their equilibrium distribution. This motion is possible only with the thermally activated jumps from one interstitial position to another. As a result, atmosphere will tend to lag behind dislocation.

INTERACTION ENERGY

The kinetics of migration of defects to dislocations is governed by the drift of defects under the influence of interaction energy E1. They will be superimposed on random jumps associated with diffusion. The path taken by the defect depends on the precise form of the angular part of E1.

$E1= A [y/(x2+y2)] = A (\text{Sin}\ ^{\theta}/r)$

A defect will tend to follow a path which is perpendicular to the constant energy contour thereby making its way into the core region.

In study involving aluminium alloys used in automotive sectors, it was found that Portevin-LeChatlier (PLC) effect caused by Cottrell atmosphere, showed a reduction in fracture elongation and uniform elongation leading to a decrease in the strain-hardening co-efficient. The overall increase in strength of aluminium alloys could be explained inter alia by the activation energy which is directly proportional with the rise and fall of temperature. As temperature was reduced, interaction energy also reduced and eventually, a fall in the strength of aluminium alloy was noticed.

In the matrices of metallic alloys of Fe, Cu, Ag, Si, etc., the combination of sufficiently high concentration of defects and a significant value of defect-dislocation interaction energy leads to point defect concentration enrichment around a dislocation. This will form the Cottrell atmosphere. The magnitude of the interaction energy under high stress will be reduced significantly when the metals are doped with donor impurities like P, As, Sb. They increase the dislocation velocity. On the other hand, on doping metals with electrically inactive impurities like C, O, N; there is very little effect on the interaction energy and dislocation velocity. Similarly, acceptor impurities also like B, also have very little effect on dislocation velocities.

DIFFUSIVITY

At sufficiently high temperatures, the solute atoms are mobile enough that they can diffuse to dislocation and thus lower their energies. The temperature must not be too high because, the entropic effect can disperse the solute again. Despite overall low solute concentration levels, the diffusion of solute atoms to dislocations tends to raise the concentration. As a result, the stress required for the dislocation to move increases. At sufficiently high stress levels, the dislocations may tend to break free from the solute clouds. In such cases, annealing can cause the solutes to diffuse back to the dislocation.

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