Some well-known empirical laws of recrystallization are:

1. The higher is the degree of deformation, the lower is the recrystallization temperature.
2. The finer is the initial grain size, the lower is the recrystallization temperature.
3. Increasing the amount of cold work and decreasing the initial grain size produce finer recrystallized grains.
4. The higher is the temperature of cold working, the less is the strain energy stored in the material. The recrystallization temperature is correspondingly higher.
5. The recrystallization rate increases exponentially with temperature.

The recrystallization temperature is strongly dependent on *the purity of a material*. Very pure materials may recrystallize around $0.3T_m$, while impure materials may recrystallize around $0.5–0.6T_m$. For example, aluminium of 99.999% purity recrystallizes at 75°C (348 K = $0.37T_m$). Commercial aluminium recrystallizes at 275°C (548 K = $0.59T_m$). The recrystallization temperature T_r of some pure metals are compared with the melting point T_m as shown in Table 9.5. The ratio of T_r/T_m lies in the range 0.35–0.5.

During recrystallization, the impurity atoms segregated at the grain boundaries retard their motion and obstruct the processes of nucleation and growth. This *solute drag effect* can be exploited in raising the recrystallization temperature in applications where the increased strength of a cold worked material is to be maintained at the service temperature without letting it to recrystallize.

Recrystallization is also slowed down in the presence of second phase particles. When the particle lies in the migrating boundary during recrystallization, the grain boundary area is less by an amount equal to the cross-sectional area of the particle. When the boundary moves out, it has to pull away from the particle and thereby create new boundary area equal to the cross-section of the particle. This increase in energy manifests itself as a *pinning action of the particle on the boundary*. Consequently, the rate of recrystallization decreases.

Grain growth refers to the increase in the average grain size on further nealing, after all the cold worked material has recrystallized. As a reduction in e grain boundary area per unit volume of the material occurs during grain owth, there is a decrease in the free energy of the material. Consider a curved ain boundary. The atoms on one side of the boundary have on an average ore nearest neighbours than on the other side. Therefore, the atoms tend to mp across the boundary to increase their overall bond energy. It is easy to see at the boundary must move towards its centre of curvature for the atoms to go to a position of greater binding. This results in a tendency for larger grains to ow at the expense of smaller grains. As the grains grow larger, the curvature of e boundaries becomes less. The rate of grain growth decreases orrespondingly. The state of binding on either side of a planar boundary is the ame and, therefore, a planar boundary tends to remain stationary.

In practical applications, grain growth is usually not desirable. Incorporation of impurity atoms (which give rise to the solute drag effect) and insoluble second phase particles (which produce the pinning action on migrating boundaries) are effective in retarding grain growth as well.

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