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3.205 Thermodynamics and Kinetics of Materials—Fall 2006

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Kinetics Lecture 12: Grain Growth; Time-Temperature-Transformation Curves

Lecture References

1. Porter and Easterling, *Phase Transformations in Metals and Alloys*, Van Nostrand Reinhold (International), Wokingham, 1988. Sections 3.3.4, pp. 130–139 and 5.4, pp. 287–290.

2. Balluffi, Allen, and Carter, *Kinetics of Materials*, Section 15.2, "Grain Growth," pp. 373–379, and Section 21.2, "Time–Temperature–Transformation Diagrams," pp. 538–540.

Key Concepts

- Grain growth is an important phenomenon in polycrystalline materials because materials properties such as strength and electromigration resistance are very sensitive to grain structure.

- Grain growth capillarity-driven, and the assumption that velocity is proportional to driving force enables grain growth kinetics to be modeled quantitatively. For two-dimensional grain structures (such as in a thin film with grain size $>$ film thickness) the growth of a given grain depends on the number of neighboring grains, N, according to the "$N - 6$" rule: grain area decreases for $N < 6$, is constant for $N = 6$, and increases for $N > 6$. There is no known analogy to the "$N - 6$" rule for growth of grains in three-dimensional grain structures.

- In both two- and three-dimensional grain growth, the growth kinetics are parabolic in time, i.e., $\langle R \rangle^2 \sim t$.

- *TTT* diagrams illustrate the kinetics of an isothermal phase transformation process on a temperature vs. time plot. Curves on the diagram connect points of equal volume fraction transformed, and typically show a curve near the "start" of the transformation (e.g., 0.01 fraction transformed) and near the "finish" of the transformation (e.g., 0.99 fraction transformed). *TTT* diagrams can be derived from experimental studies or from kinetic models. Curves of constant fraction transformed have a characteristic "C" shape.