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GRAIN GROWTH IN ONE DIMENSION: THE MEAN FIELD APPROACH

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ABSTRACT

In order to assess the accuracy of the mean field approximation to the kinetics of grain growth, we introduce a one-dimensional model of a polycrystal, in which the grains are segments in a line, with periodic boundary conditions, each grain having two adjacent grains. The size of each grain changes with time according to a given law, the rate of change depending on the size of the grain and on the sizes of the adjacent grains, in such a way that small grains shrink, eventually disappearing, and large grains expand, with conservation of total size. In a mean field approximation, the adjacent grains are replaced by grains of average size.

The evolution of various initial distributions under the two approaches, i.e. the discrete and the mean field approaches, is compared. Large differences between the two approaches are found for particular initial distributions, while for other distributions the differences are minor. The kinetics is, in general, faster in the discrete approach, and leads to broader distributions than in the mean field approximation. Steady state distributions within the mean field approach are seen to evolve in the discrete approach. No tendency for a steady state to be reached has been observed, the distributions becoming in general broader due to growth.

INTRODUCTION

Grain growth is a cooperative phenomenon in that the change in size and shape of a grain depends not only on the size and shape of the grain itself but also on the size and shape of the neighbours which contact it at grain boundaries. Several computer simulation models of grain growth, usually bi-dimensional (reviewed in ref.1), have been developed in recent years which, in a way or another, incorporate the effect of neighbours. From the computer simulations it is possible to study the evolution in time of various geometrical and topological characteristics of the grains, particularly the evolution of the grain size distribution and that of the average grain size.

Because the various simulation models differ in the assumed mechanisms responsible for the movement of grain boundaries and triple points, and, on the other hand, use different initial polycrystals, they lead to different results and it becomes difficult to establish from them the general laws of grain growth, e.g. the time dependence of the average grain size.

A completely different and simpler approach to grain growth, which can be termed the mean field approach, consists of assuming that each grain is surrounded by grains of average size (see Hunderi and Ryum [2]). Topology is excluded from this approach. The rate of change of the size of a grain then depends exclusively on its size and on the average grain size and/or on some other moments of the size distribution.

Grain growth occurs at constant total volume, the larger grains growing at the expense of the smaller grains, which shrink and disappear, being "incorporated" in the larger grains. The constancy of