Grain growth: the mixed control mechanism of atom transport

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Ever since its inception, the kinetics of boundary migration and grain growth has been described to be linearly proportional to the associated driving force, irrespective of the presence of impurities, second phase particles or a liquid film at the boundary, as well as any anisotropy in energy or mobility of the grain boundary. Whenever diffusional material transport occurs from one place to another, there are always sources and sinks of atoms. Therefore, the resultant transport kinetics can be governed by either the kinetics of atom movement (diffusion) from the source to the sink or the reaction of atoms at the interface of the source or sink. A typical example is the growth of a single crystal from a melt. It is well documented that the crystal growth mechanism and kinetics is highly dependent on the surface structure of the crystal. For a faceted crystal with an atomically ordered surface, the growth mechanism is either interface reaction- or diffusion-controlled below or above a critical driving force. This mechanism is called the mixed control mechanism. A similar idea may also be valid for the migration of grain boundaries as boundary migration occurs via thermal jumping, which can be considered as diffusion, of atoms across the boundary and their placement (interface reaction) on the surface of the growing grain. Some previous HRTEM observations show that the migration of a flat (faceted) boundary occurs via a lateral spreading of atoms from kink sites formed on the surface of the advancing grain, similar to the growth of a faceted crystal from a melt. Our experimental observations indicate that the mixed control mechanism is operative in the migration of faceted (flat) grain boundaries and resultant grain growth.

This presentation first discusses the limits of the conventional concept of boundary migration. It then describes the basis of the mixed control mechanism of atom transport across the boundary. The mixed mechanism principle of microstructural evolution, which we deduced a decade ago, is explained. We provide examples, which were obtained not only from ceramics but also metals, for the generality of the microstructural evolution principle.[1.2] Some future research directions for boundary migration and grain growth will also be commented on and suggested.

[1]S.-J. Kang, et al., *J. Am. Ceram. Soc.*, 92, 1464-71 (2009).
[2]S.-J. L. Kang et al., *J. Am. Ceram. Soc*., 98, 347-60 (2015)