Interface Roughening, Grain Growth, and Sintering

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One of the important works of Professor In Hyung Moon is the observation of activated sintering in W-Ni and the suggestion that the small amount of Ni increases the grain boundary diffusion rate. It is possible that such an effect arises from the grain boundary roughening transition induced by Ni in W. Crystal surfaces and grain boundaries at low temperatures are flat usually lying on the low index planes. These interfaces are singular corresponding to cusps in the polar plots of the interface energy against their orientation. At high temperature these singular interfaces can become rough at atomic scale and may undergo roughening transitions at critical temperatures below the bulk melting points. Theoretical analysis and computer simulations (Monte Carlo and molecular dynamics) show the possibility of such roughening transitions of both solid-vapour interfaces and grain boundaries. Experimentally, the changes of flat interface shapes to curved ones at all magnifications indicate the roughening transitions in both metals and ceramics. The roughening transition can also be induced by additives as well as by temperature increase. The kinetic properties also depend on the roughening transition. The singular interfaces, if free of defects, move by two dimensional nucleation of steps, and in the system of many grains, the grain growth will be abnormal. The rough interfaces move continuously and hence the grain growth is normal. The interface diffusivity can also depend on the roughening transition as shown, for example, by Lee, et al. The grain shape changes indicate that small amounts of Ni in W can induce the roughening of both surfaces and grain boundaries, thereby increasing the interface diffusivities. Kang, et al. also showed that the sintering of oxides could be enhanced by grain boundary roughening. While the study of the surface roughening has been relatively extensive, the grain boundary roughening and its effect on diffusivity and sintering need to be examined more extensively.