SINTERING OF UNEQUAL GRAINS

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EXTENDED ABSTRACT

The bonds are of fundamental importance in snow, and my photographs (J. Appl. Phys. 84, 4585, 1998) of the bonds in snow clearly showed that the geometry of the bond is dominated by a grain boundary groove, not the smooth bond neck that had long been assumed. That theory has been extended to grains of different sizes. As with equal grains, the rate of bond growth drops rapidly as sintering proceeds, and it approaches zero as the equilibrium values of the sizes and angles are approached.

The absolute values of the sizes and the relative sizes are both important. Restrictions on the geometry of the grains show that, as the ratio of the grain sizes increases, the grain boundary between the grains becomes more highly curved, and the smaller grain becomes more deeply embedded in the larger grain. When the ratio is large enough, the smaller grain can only be a small mound on the surface of the larger grain. At a ratio of grain sizes of only 1.57 or greater, the exposed portion of the small grain is too small to allow it to bond to a third, larger. grain. In this condition the small grain cannot connect to a chain of grains that includes two grains that are larger than itself. Accordingly, the small grain could not be part of a chain that binds the material together. This is a significant restriction on how adjacent grains can bond to form the network of grains in snow. It explains why snow grains do not bond readily to an icy surface.

When the grains are similar, the rate of bond growth is quantitatively and qualitatively similar to the rate for equal grains. However, when the grains are of different sizes, the stress gradient in the grain boundary decreases, and the grain boundary becomes more tightly curved. Both of these effects decrease the rate of bonding, the first because the flux rate in the grain boundary decreases and the second because the path length for the flux increases.

When put in dimensionless form, the time for sintering depends only on the ratio of the sizes and is independent of the absolute sizes of the grains. Thus, the dimensionless time to sinter increases with the ratio of the grain sizes owing to the two effects of reduced stress and increased path length. However, the real time for sintering is proportional to dimensionless time times the fourth power of the radius of the grain boundary, so the real time for sintering increases as both the ratio of the sizes of the grains and their absolute sizes. For a given ratio of sizes, the radius of the grain boundary is proportional to the radius of either grain, so the time for sintering increases as the fourth power of the grain size, just as it does for grains of equal size.

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