relations were observed in the "inhibition-dependent coarsening" of Al alloys containing a dispersed phase. However, the behavior of the 90 pct rolled copper strip, which has a cube recrystallization texture, is different. Up to 4 hr it does not coarsen at all at 800°C. It coarsens at 1000°C in 3 to 6 min, in a manner typical of "texture-dependent coarsening" (Fig 2).

It may be concluded that coarsening at 800°C, after 30 to 70 pct reduction by rolling, may develop in straight rolled as well as in cross rolled tough pitch copper. This confirms the view that coarsening in Cu₂O-containing copper after 30 to 70 pct rolling is analogous to the coarsening in alumi-

num containing dispersed particles of a second phase.

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Solid Nuclei in Liquid Metals

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THE partial persistence of grain size and grain shape on melting and re-solidifying crystalline substances, as well as the general effects of pre-solidification and of superheating on nucleation rate, have been attributed to the presence in the liquid of crystalline impurities bearing some structural relation to the principal solid and hence capable of serving as nuclei for its crystallization. That such lattice matching does sometimes occur is well established, but it is surely improbable that a compound possessing both high-temperature stability and the requisite structural similarity should be naturally available in almost every system.

It is now suggested that a mechanism for producing appropriate nuclei exists in the crystallization of all but absolutely pure substances. Impurities can be of many kinds. Some will give rise to compounds that are less soluble in the solid crystal than in the liquid. A crystal forming from a melt or solution containing these will be supersaturated in some degree, and the foreign atoms will commence to segregate during or after solidification. They do not necessarily form pure, unstrained, crystals of the precipitating compound with its normal composition and structure. Generally—at least in the metallurgical examples that have been most studied—the first recognizable nuclei have lattice coherency with the surrounding matrix and have practically the same crystal structure and lattice spacing as the material in which they form, differ-

ing only in composition.

An extremely thin oxide layer formed under appropriate conditions on or in a solid metal will tend to be coherent with the metal lattice, and the first few atom layers of the oxide in contact with the metal will differ in both composition and structure from massive crystalline oxide. It will resemble the metal more closely than the oxide. If it did not subsequently change on melting, such an oxide film would constitute an almost perfect "template" or two-dimensional matrix to hold a few atoms of the primary metal in the exact array needed to form a nucleus for solidification.

Any precipitating material will adopt the correct spacing over a few atom diameters, and with appropriate substitution of other atoms of the correct sizes a precipitate can match the parent lattice over large areas of coherence without excessive strain. In metals, the components of a host of oxides, silicides, borides, nitrides, carbides, sulphides, and other compounds are always present in minute amounts. Some of these will be eliminated because of extreme insolubility in the liquid, while others will remain soluble in the solid; occasionally, however, particles will be formed in the solid by coherent precipitation—not of pure substances, but of whatever assortment of atoms best

satisfies the joint requirements of availability, affinity, and appropriate average atom size. Of these, many will disappear on melting, but a few will persist unmelted as little rafts of complex composition, maintaining in the liquid a surface of the exact geometry needed to nucleate the solid on subsequent cooling. Their number and size distribution will determine the resulting grain size; the dimensions of the largest will determine the degree of undercooling that can occur before solidification commences.

A similar process may operate in the case of phase transformations in solids. The coherent precipitation of supersaturated minor constituents in a low-temperature phase should facilitate the nucleation of this phase on subsequent cooling after transforming into another phase at higher temperatures.

At first sight this hypothesis may seem little different from the older ones. It should therefore be emphasized that it does not depend on chance to provide the right compound to form a nucleus, but postulates that every crystal, containing minute amounts of any of a wide range of impurities, automatically engenders particles having the correct surface structure to serve as nuclei for subsequent solidification. It could operate in any system, metallic, organic, or inorganic. The suggested mechanism is closely analogous to the production of antibodies from antigens in living organisms—indeed, it was a description of the matrix theory of this process that suggested to the writer its crystalline analogue.

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