Sintering is the heating process through which the particle contacts achieved during powder compaction grow, and the physical and mechanical properties of a part are developed. Frequently, it is accompanied by shrinkage of the part. Sintering can also involve alloying and homogenization of mixed powder parts, often accompanied by growth.

Sintering depends on two things: the high surface area of the particles, and the fact that at high temperatures, the particles minimize surface area by becoming more spherical. As the spheres contact one another, the active surface atoms of each exchange electrons and establish metallic bonds. As sintering continues, more and more such bonds are formed, until all the particles are bonded and the part is completely sintered.

Sintering is carried out at temperatures around 66% of the absolute melting point of the material, typically for 20 to 60 minutes, and under a protective atmosphere to prevent oxidation or nitridation.

In the early stage of sintering, bonds form at the particle contact points, a process called necking, as shown in the photo. During intermediate stage sintering, in the density range of approximately 70 to 92% of theoretical, the rate of sintering slows, the powder grains grow, and pores become isolated. In the final stage, spherical and isolated pores shrink only slowly, by vacancy diffusion to grain boundaries.

The sintering process is driven mainly by the surface energy of the powder particles; therefore, a fine powder sinters more rapidly than a coarse powder. This is the reason that metal injection molding (MIM) requires very fine powders, 5 to 20 microns, which under normal sintering conditions shrink to nearly full density.

In liquid phase sintering, a molten metal such as copper coexists with the solid phase during part of the sintering process, or sometimes for the entire process. The presence of the liquid, through a solution re-precipitation process, enables more rapid sintering and much faster densification than is typical for a solid state system. Thus, with a liquid phase sintering system, it is possible to achieve a high sintered density without a fine powder. Commercially, widely used liquid phase sintering systems include bronze (for porous bearings), copper steels, tool steels, cemented carbides, iron-phosphorous, and tungsten-nickel.

In activated sintering, a small amount of an additive is used to improve the diffusion rate during sintering. Examples include palladium added to tungsten, and hydrogen chloride added to hydrogen atmospheres for sintering iron compacts.

This information is from the ASM Desk Editions online —> Metals Handbook Desk Edition —> Powder Metallurgy —> Powder Consolidation —> Sintering.