Alloying elements commonly added to brass: resulting properties and uses

Aluminum
Aluminum added as the principal alloying element to copper forms a series of high strength alloys called aluminum bronzes. Aluminum forms solid solutions with copper up to about 9.5 wt%. High strength yellow brasses contain aluminum in varying amounts.

Arsenic and Antimony
Arsenic and antimony can be added in small quantities, up to about 0.05 wt%, to all brass alloys containing less than 80% copper to inhibit the dezincification types of corrosion in yellow brass alloys.

Beryllium
Beryllium added to copper forms a series of age- or precipitation-hardenable alloys. These heat-treatable alloys are the strongest of all known copper-base alloys.

Chromium
Chromium added to copper forms heat-treatable copper alloys.

Iron
Iron added to copper alloys adds strength to the silicon, aluminum, and manganese bronzes. It combines with aluminum or manganese to form hard, intermetallic compounds. Undissolved iron in the alloy leads to nonuniform hardness and interferes with machining.

Lead
Lead is added to copper in amounts up to 40 wt%. Lead is insoluble in copper-based alloys and because of its low melting point is found distributed in the grain boundaries of the casting. Because lead imparts a certain degree of brittleness to the structure, it enhances machining operations by causing the alloy to break into chips as cutting tools are thrust into the matrix. Additions of lead up to 1.5 wt% significantly improve machinability without a serious decrease in tensile strength. Lead concentrations of 5-25 wt% greatly increase machinability of the alloy but with a resulting decrease in tensile strength. Alloys with lead concentrations equal to or greater than the tin content are used for bearing applications requiring resistance to both wear and friction. Lead added to copper in amounts of about 35-40 wt% forms a useful bearing alloy. However, lead is considered undesirable in high strength manganese bronze, silicon bronze, and silicon brass. It affects the surface of silicon bronze and silicon brass, causing noticeable darkening and pockmarking.

Manganese
Manganese is added as an alloying element in high strength brasses where it forms compounds with other elements such as iron and aluminum. Manganese may also be used as a deoxidizer, although it is not a common usage.

Nickel
Nickel added to copper markedly whitens the resulting alloy. Cupronickel alloys contain 10-30 wt% nickel and have very high corrosion resistance. Iron, up to a nominal 1.4 wt%, added along with nickel significantly enhances the resistance toward impingement corrosion. Added to bronzes, nickel refines the cast grain structure and adds toughness. Nickel improves strength and corrosion resistance. An alloy series containing 10-25 wt% nickel, along with tin, lead, and zinc as principal alloying elements, is known as the nickel-silvers. Nickel is added up to about 1 wt% to some of the high tingear bronze alloys to enhance wear properties.

Phosphorus
Phosphorus is used principally as a deoxidizer in copper and high copper alloys. The alloy should contain a minimum residual of 0.02 wt% phosphorus to ensure complete deoxidization. Lesser amounts of residual phosphorus can form an equilibrium system with copper and oxygen. Phosphorus can be added in small quantities,

up to about 0.05 wt%, to all brass alloys containing less than 80 wt% copper to inhibit the dezincification types of corrosion in yellow brass alloys.

Silicon
Alloys of high strength and toughness along with improved corrosion resistance, particularly in acidic media, result when silicon is added to copper. Silicon in small amounts can improve fluidity.

Tin
Tin added to copper in concentrations of 5-20 wt% forms the tin-bronze alloys series. Leaded tin bronze is also produced. Typically a deoxidizer is added to the melt to produce a clean structure. Tin imparts strength and hardness to copper-base alloys, making them tough and wear resistant. It also enhances the corrosion resistance of copper-base alloys in nonoxidizing media. Small amounts of tin, 3-5 wt%, are added to leaded red brass and semi-red brasses to increase the strength and hardness of the alloys. In high tensile strength manganese-bronze, tin is limited to a maximum of 0.2 wt% as it lowers the tensile strength and ductility of the alloy.

Zinc
Zinc is added to copper as a principal alloying element in concentrations of 5-40 wt%, forming the alloy series known as brasses. Zinc increases the tensile strength at a significant rate up to a concentration of about 20 wt%, then the tensile strength increases only slightly more for additions of 20-40 wt% zinc. Zinc up to 5 wt% is added to tin bronze alloys to tighten the structure and to act as a deoxidizer. In yellow brasses zinc imparts a freedom from gas porosity because when the melt is heated until the zinc boils, the zinc vapors sweep the melt free of gas. Cast copper-zinc alloys are described as red brasses and leaded red brasses, semi-red, silicon, yellow and high strength yellow brasses. Red brasses and yellow brasses contain zinc as the principal alloying element, along with some tin and lead or other designated elements; however, yellow brasses contain significantly more zinc than the red brasses. Semi-red brasses contain less copper than do red 42 brasses. High strength yellow brasses are alloys that contain zinc with smaller amounts of iron, aluminum, nickel, and lead.

Source: United States Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances; and Office of Information Analysis and Access, (Office of Environmental Information), 2001, Report on the Corrosion of Certain Alloys, EPA 260-R-01-002, 71 pp.