Adding Phosphorus to Hypereutectic Silicon-Aluminum Using 8% Phosphorus-Copper

Phosphorus has been shown to be an effective nucleant for primary Silicon in hypereutectic Silicon-Aluminum alloys (Si >12%). The addition of Phosphorus to Aluminum is difficult because it:

1. Is highly volatile at the temperature of the bath.
2. Oxidizes readily at the metal surface.
3. Forms a less dense AlP compound that separates to the surface dross.

A successful method of adding Phosphorus to Aluminum is to add pre-alloyed Phosphorus-Copper compounds.

Phosphorus-Copper is commercially produced in two compositions, 8% P-Cu and 15% P-Cu. Above 15%, Phosphorus is insoluble in Copper. At 15% P, the alloy is nearly 100% Cu_3P, the most concentrated form of Phosphorus in Copper. At 8% P, the alloy forms an eutectic (lowest melting composition) mixture of Copper with Cu_3P. Both Phosphorus-Copper compositions are manufactured as shot, usually to a controlled size.

Consider the reactions necessary to refine the primary Silicon crystals in hypereutectic Silicon-Aluminum. The Cu_3P must react with Aluminum such that

$$Cu_3P + Al \longrightarrow AlP + 3Cu.$$

The Copper must be dissolved and alloyed with the Aluminum. The Phosphorus must be won away from the Copper compound (Cu_3P) and the raw compound AlP must be formed.

1. The AlP formation is highly exothermic, and the particles of AlP would be hotter than the bath surrounding them.
2. The AlP, being less dense, tends to float to the surface.
3. At the surface, the AlP readily reacts with air to form Aluminum Oxide and Phosphorus Pentoxide.

The addition of 15% P-Cu will aggravate these three negative influences of the AlP formation in the bath. By using 8% P-Cu, the amount of local Phosphorus at the reaction/dissolution site is reduced, hence the superheat and the volume of AlP formed is reduced. The buoyant tendency of AlP may be overcome by surface tension phenomenon and the nucleant will reside in the bath longer.

By reducing the particle size of the 8% P-Cu, there is further reduction in the local Phosphorus concentration at the reaction/dissolution site. Thus, the above exothermicity and density factors are mollified. Using a (3/8" x 1/16") shot size is far better than a coarser material.

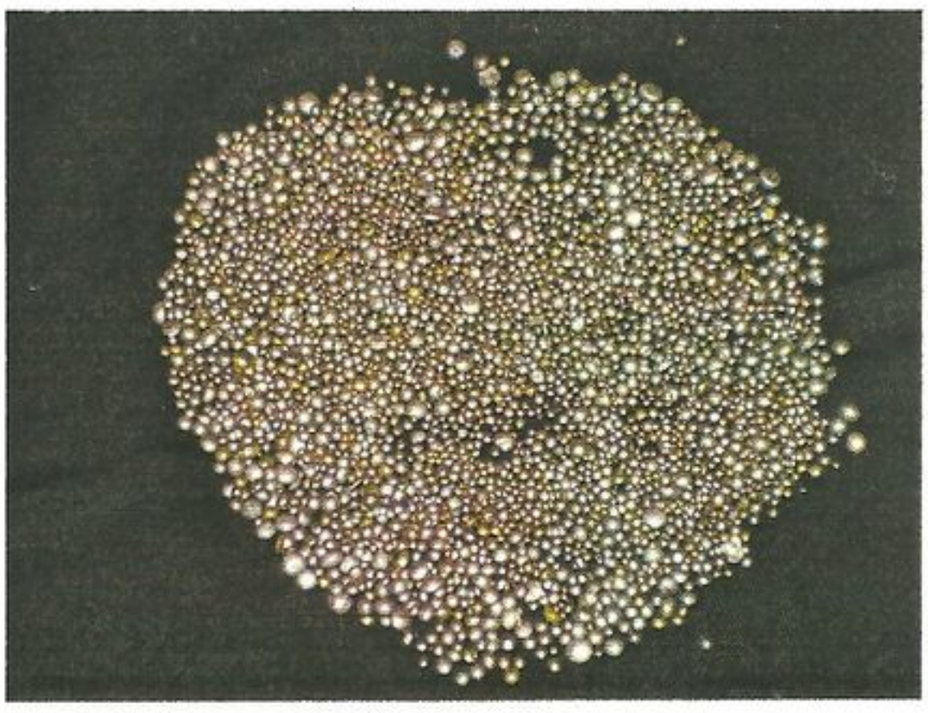
Because 15% P-Cu has a higher Phosphorus concentration than 8% P-Cu, it will more readily react with moisture and air to form a complex Copper-Phosphorus-Oxygen coating on the shot surface. This coating contains hydrated P_2O_5 and CuO and entraps moisture as well. The combination of hydrated oxides makes 15% P-Cu more difficult to react with Aluminum to successfully produce AlP nuclei.

In conclusion, Milward Alloys recommends inoculating hypereutectic Silicon-Aluminum alloys with

8% Phosphorus-Copper (3/8" x 1/16") shot

because:

1. 8% P-Cu is more compatible with the local Aluminum reaction dissolution than 15% P-Cu.
2. Less of the AlP formed is floated to the surface and lost.
3. The dispersion and distribution of the AlP formed with the 8% P-Cu is more compatible with the needs of nucleation in the Silicon-Aluminum alloy.
4. The surface integrity of 8% P-Cu is superior to 15% P-Cu for reaction dissolution in Aluminum.



Milward
Aluminum & Copper Alloying Additives

Milward Alloys, Inc
500 Mill Street
Lockport, New York 14094-1712
716-434-5536
800-833-6600