

### Microalloyed Solder Alloys – Content Does Matter

Improving the properties of lead-free solder has been in focus of research and development for several years, whereby microalloying is one of the most important approaches [e.g. 1]. A detailed analysis of a recent research work [2] confirms that due to possible interactions between the alloying elements like nickel or phosphor especially their exact content matters.

So, in ELSOLD SN100(Ag) MA-S solders the phosphor content is typically adjusted to about 40 ppm and lies in that range, which enables to use the positive effects of phosphor concerning oxidation and dross generation and also the advantages of nickel with regard to microstructure, fluidity, breakage behavior and risk of bridging. Finally the analysis of the recent research studies confirms the development results by ELSOLD and the positive experience by numerous customers.

#### ■ Influence on Microstructure

Alloying Ni improves and homogenizes the microstructure of the solder. Typical primary dendrites disappear. Consequently mechanical properties are increased and risk of crack formation is reduced [1, 2]. Even though phosphor reduces this positive effect, at phosphor contents, which are typical for MA-S alloys, a clear advantage remains. Only at 800 ppm P and more, that means factor 20 compared to MA-S, no improvement of microstructure is possible any more. [2]

#### ■ Fluidity, Breakage Behavior and Risk of Bridging

Similar to the influence on microstructure, nickel has a very positive effect on flow and breakage behavior, which is only slightly reduced by phosphor. Icicle length and consequently the risk of bridging is reduced by 65% by adding Ni, and still by 53%, if Ni and P are combined. Fluidity is improved by 32% by Ni. Adding small phosphor contents, which are typical for MA-S alloys, an improvement by 20% remains. Only at high phosphor contents (> 200 ppm) the improvement is reduced to 8%.

#### ■ Binding of Nickel by Phosphor

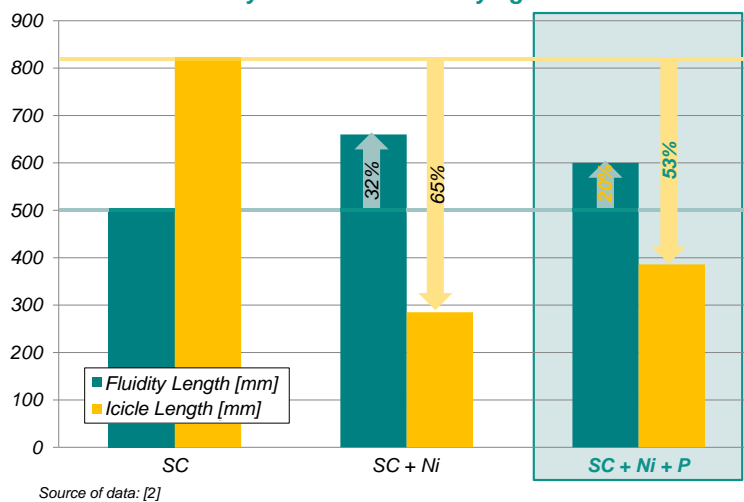
Investigations described in [3] approve that the positive effects of Ni are eliminated only by very high phosphor contents. They show a reduction of effective Ni content only at more than 500 ppm P. At lower values (about 50 ppm) a constant Ni value was detected.

#### ■ Reduction of Oxidation and Dross Generation

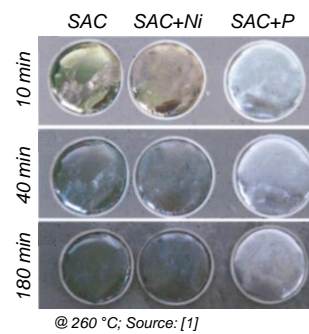
In contrast to nickel, which has no strong influence on oxidation behavior, phosphor offers important advantages in this regard. Probably by the formation of complex tin phosphor mixed oxides a protective layer on the surface prevents the solder from further oxidation and dross generation [1]. But also here, the content matters. At too high phosphor contents > 700 ppm the formation of intermediate Sn-P-phases was detected, which would damage this protection layer [4]. At lower contents of about 40 ppm, typical for MA-S solder, phosphor – combined with the similar, supporting effect of germanium and the high purity due to the special manufacturing process – creates the well-known very low dross generation of MA-S solders.

In a nutshell, nickel and phosphor each have their own specific positive effects on the properties of lead-free solders and therefore both are useful as microalloying elements. Because some of these effects are opposing, a very targeted alloying is necessary. But a complete binding of Ni and an elimination of its positive effects only happen at phosphor contents 10 times higher than typical values of SN 100 MA-S solders and no negative synergies between both elements are known. At about 40 ppm phosphor the advantages of nickel remain to a great extent and are combined optimally with a protection against oxidation and dross generation.

**Improvement of Flow and Breakage Behavior by Nickel – also if alloying P**



**Improvement of Oxidation Behavior by P**



#### Literature

- [1] W Dong, Y Shi, Y Lei, Z Xia, D Guo: Effects of small amounts of Ni/P/Ce element additions on the microstructure and properties of Sn3.0Ag0.5Cu solder alloy, *J Mater Sci: Mater Electron* (2009) 20:1008-1017
- [2] P Corviseri: Das Geheimnis Nickel-dotierter Lote, *productronic* 07 / 2013, 20-21
- [3] Patent EP 2 243 590 A1: Method of regulating nickel concentration in lead-free solder containing nickel, Nihon Superior Sha Co., Ltd Suita-shi Osaka 564-0063 (JP), 2010
- [4] AP Xian, GL Gong: Surface oxidation of molten Sn-0.07 wt% P in air at 280 °C, *J Mater Res*, Vol 23, No 6, 2008, 1532-1536