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TEM Study of Microstructure Evolution in Novel Environmentally Friendly Si alloyed Lead-free Brasses

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The progressively stricter European and American regulations (California Health and Safety Code (AV1953), Vermont Act 193, Directive 2002/95 / EC (RoHS), Drinking water directive 98/38 / EC, German DIN 50930-6, Italian DM Salute 6 aprile 2004 n.174 and French Arreté 29 Mai 1997) [1], in conjunction with lead leaching studies on drinking water, have stimulated the development of unleaded brass maximum permitting levels of Pb up to 0.2 wt%. Many studies have been contacted on lead-free brasses with several different additions, but the effect of Si content on the microstructure evolution and control, via TEM characterisation techniques has not been properly addressed to-date. Leaded brasses have 3-7%wt Pb additions, primarily for enhanced machinability characteristics, as well as improved aqueous corrosion resistance, while the lead free alloy studied ,has a composition of 75.85%wt Cu, 3.4%wt Si, 0.02%wtFe and 20.75%wtZn.

Based on this alloy composition, this eco-brass is placed close to the peritectic point, as defined by Fig.1, hence it is predicted to have in its microstructure the following three phases α(fcc), γ(bcc) and κ (hcp), while at approximately 550^{o}C the following reaction is expected to take place, $\alpha+\kappa\Rightarrow\gamma$.

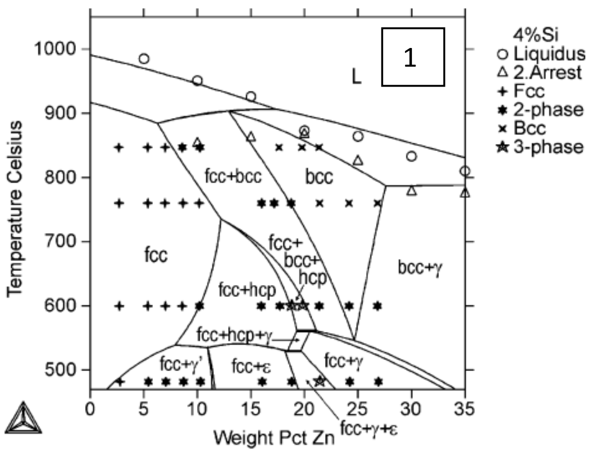
In Fig.2 the presented SEM micrographs, give an outline of the microstructure features of these three phases, appropriately marked and identified via both XRD trace analysis, as well as EDS spot-microanalyses. α-phase has an fcc crystal structure (fcc, Fm3m), κ-phase an hcp (hcp, P63/mmc) and γ-phase a bcc crystal structure (bcc, I43m). In addition, to these principal phases the presence of a minor intermetallic, Fe_xSi_y, precipitate was detected both within γ and κ phases (fig.2). From the detailed EDS microanalyses performed both on the SEM and on the TEM, it has been confirmed that α phase has a composition of 1.78±0.28Si, κ phase, 3.55±0.29Si and finally γ phase is significantly enriched in Si, having an average composition of 5.94±0.38 Si. α–phase is also prone to formation of Widmanstatten needles upon cold deformation.

The fine details of the TEM microstructures for κ and α phases microstructures, are given in Fig.3, while for g phase in Fig. 4. The heavily dislocated substructure is evident in both micrographs, as well as the presence of Widmanstatten needles with α phase and deformation twins within κ-phase.

The present study has highlighted the important modification on microstructure features present in Si alloyed eco-brasses, a result of Pb replacement by Si. The refined microstructure of g phase, with its enhanced Si content, is considered to be crucial for attaining suitable machinability characteristics in eco-brasses. It is envisaged that with revised thermomechanical processing routes applied, fine tuning of the excellent machinability characteristics and aqueous water corrosion resistance will be attained.

References:

[1] G. Mueller.: Proceedings of the IWCC General Assembly, (2009), p.7.
[2] J.Miettinen, Computer Coupling of Phase Diagrams and Thermochemistry, Vol.**31**(2007) , p.422.



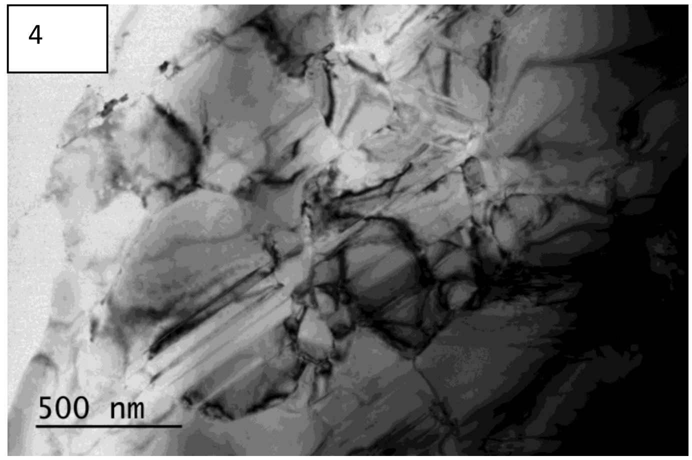


Figure 1. Cu-Si-Zn phase diagram for a 4%wt Si addition [2].

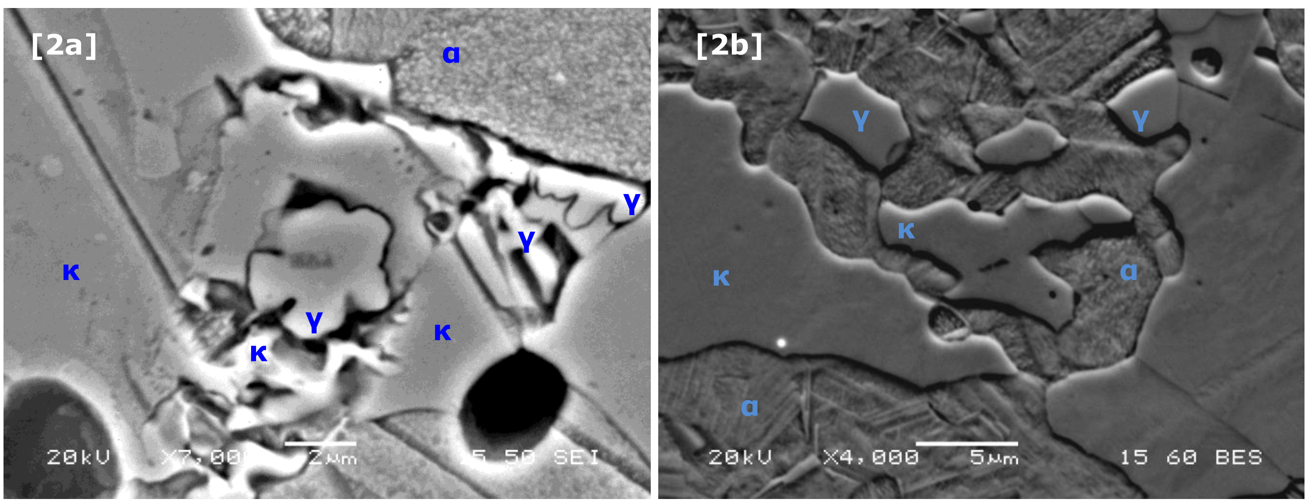
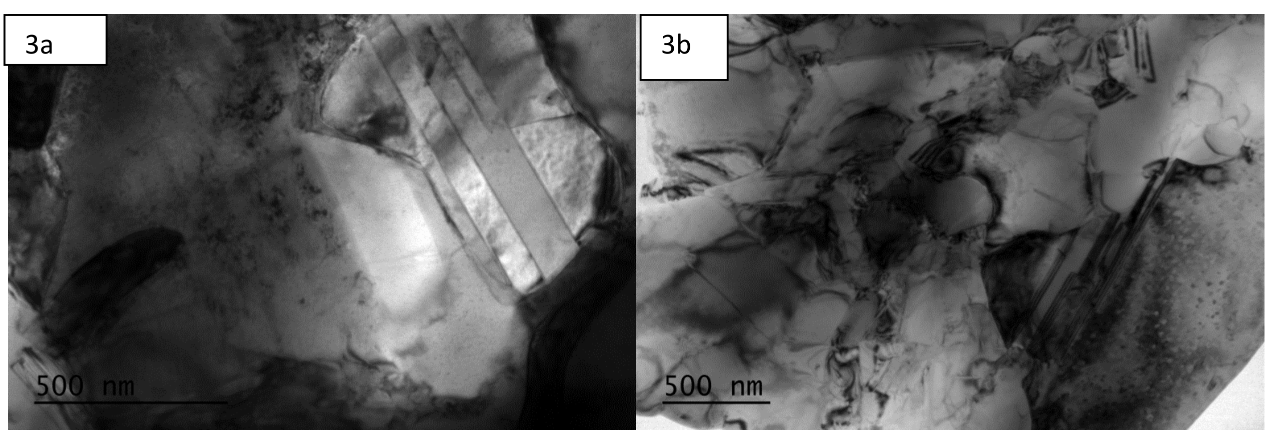


Figure 2. Secondary (2a) and Backscattered (2b) micrographs , outlining the morphological features of α, κ and γ phases , as well as the Fe_xSi_y intermetallic phase, within γ-phase(2a) and within κ phase (2b).



Figures 3 and 4. TEM bright field micrographs of κ-phase (3a), α-phase (3b) and γ phase (4), within a heavily dislocated substructure in as received eco-brass.