UNIVERSITI TEKNOLOGI MARA

KAMPUS ARAU PERLIS

BACHELOR OF SCIENCE (HONS.) PHYSICS

FACULTY OF APPLIED SCIENCES

THE EFFECT OF NON-METALLIC DOPANTS ADDITION ON THE PROPERTIES OF LEAD-FREE SOLDERS – A REVIEW

NURATHIQAH BINTI BAHARUDDIN

SUPERVISOR:

PROF. MADYA DR RAMANI A/L MAYAPPAN

AUGUST 2022

Abstract

The objective of this review is to study the effect of non-metallic dopants addition on the properties of lead-free solder. These properties are important as it portray a good solder that can be used in electronic devices. Variety of lead-free solder and non-metallic dopants are being analyzed by using previous study by other researchers. This review is focusing on the influence of variety non-metallic dopants in the melting temperature, intermetallic, solder joint strength and electrical properties, as full understanding of the process that determine a good and reliable solder, which can replace the hazardous lead solder. At the end of this review, the effects of non-metallic dopants addition are explained which have affect the properties of lead-free solder.

1. Introduction

Medical research has shown that lead is a toxic heavy metal that can harm humans. It can disrupt the human brain system, kidneys, blood circulation, and reproductive system (Vidyatharran et al., 2021). As a result of this understanding, legislation prohibiting the use of traditional Sn-Pb solder alloys has been enacted to promote the use of lead-free solder materials as potential connecting materials in modern electronic goods. Many researchers are interested in replacing the traditional Sn-Pb with lead-free solders (Mayappan et al., 2020).

Sn-Ag-Cu turned out to be the most preferred and commonly recognised as lead-free solders for its environmental friendliness, excellent comprehensive mechanical properties, and acceptable solderability (Vidyatharran et al., 2021). Unfortunately, some issues have occurred with lead-free solders, where the quality is not as good as lead solder. Thus, non-metallic elements have been added to change the microstructure and improve other qualities.

Research has been done on how the addition of non-metallics dopants in solder joints improves the lead-free solder’s properties. According to Nur Syahirah et al. (2020), composite solder was thought to be a promising possibility for enhancing the performance and attributes of existing solder alloys by introducing reinforcing particles. Carbon nanotubes (CNTs) and graphene nanosheets (GNSs) were also suitable for doping in soldering because they offer better mechanical, electrical or shear strength properties for the lead-free solder and reduce the intermetallic layer by preventing the growth (Muhammad Aamir et al., 2020). A study from Sun et al. (2018) mentioned that excessive dopants in solder joints could cause unwanted defects in the formation of the intermetallic layer and a decrease in the quality of solder joints. This can cause the accumulation of dopants in solder, resulting in fracture or cracks. So, choosing optimum and reasonable amounts of dopants is necessary to avoid defects.

2. Effect of non-metallic dopants on melting temperature

2.1 The effect of graphene nanosheets (GNSs) on melting temperature of lead-free solder

2.1.1 The effect of GNSs on the melting temperature of Sn-0.7Cu

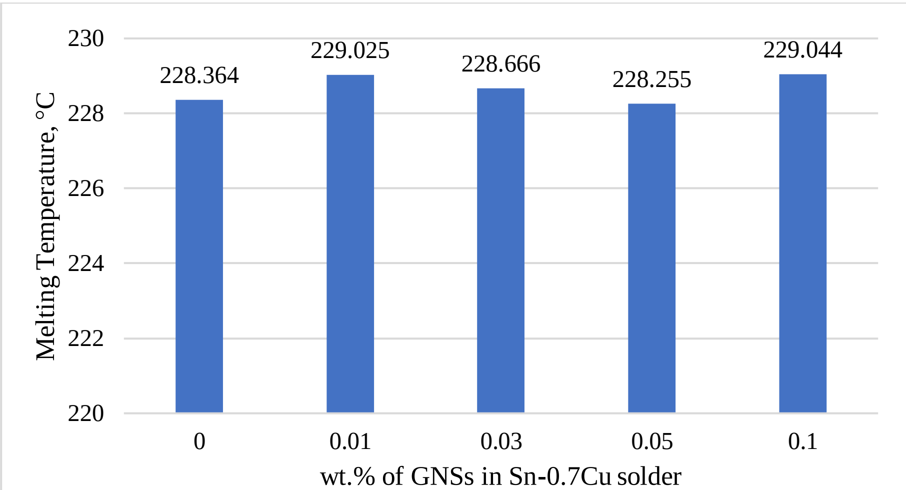

Figure 1: Temperature of Sn-0.7Cu and Sn-0.7Cu/GNSs with different wt.% of GNSs (Yang et al., 2020).

From Fig. 1, most of the solders show an identical range of temperature between 228.255 °C and 229.044 °C. This can also be concluded that there is only one phase transformation process in the solder. The melting temperature of the solder that contained graphene nanosheets (GNSs) is hardly changed by 0.789 °C. This demonstrates that GNSs have only a minor impact on the melting temperature of Sn-0.7Cu solder.

GNSs is a high melting point reinforcing phase, which can be the main reason for the slight difference in the melting temperature. Other than that, the high melting point phase Cu_6Sn_5 is decreased by adding GNSs, lowering the melting point. This also results in small changes in the melting point. Surface free energy rises, causing the surface tension to also increase during the melting process (Yang et al., 2020).

2.1.2 The effect of GNSs on the melting temperature of Sn-3.5Ag

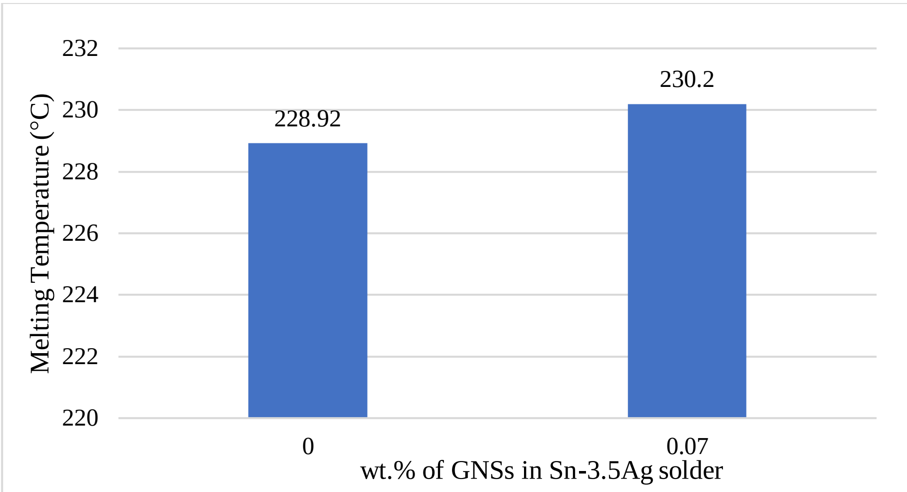

Figure 2: Melting temperature of Sn-3.5Ag with and without 0.07 wt.% of GNSs (Mayappan & Salleh, 2017).

Sn-3.5Ag solder has lower melting temperature compared to the solder with GNSs addition which are 228.92 °C and 230.2 °C respectively. Based on Mayappan & Salleh (2017) study, the improvement of melting temperature in Sn-3.5Ag is caused by the addition of GNSs dopant. This addition changed the variation in physical properties of grain boundary and surface instability of Sn-3.5Ag solder.

2.1.3 The effect of GNSs on the melting temperature of Sn-0.3Ag-0.7Cu

Table 1: The temperature peak point of Sn-0.3Ag-0.7Cu without and with different addition of wt.% GNSs (Yin et al., 2020).

Composite Solder	Tpeak
Sn-0.3Ag-0.7Cu	222.7
Sn-0.3Ag-0.7Cu/0.01GNSs	221.0
Sn-0.3Ag-0.7Cu/0.03GNSs	220.6
Sn-0.3Ag-0.7Cu/0.05GNSs	220.5
Sn-0.3Ag-0.7Cu/0.07GNSs	220.6
Sn-0.3Ag-0.7Cu/0.09GNSs	219.6

The temperature at the peak point was 219.6 °C when 0.09 wt.% of GNSs is added. The temperature reduced by 2.3 °C when compared to the pure Sn-0.3Ag-0.7Cu solder. According to Yin et al. (2020), the atomic diffusions is hindered by the addition of GNSs, thus allowing the sintered solder's structure and grain to be refined. The solder interface also increases by the homogeneous distribution of GNSs, resulting in the increased energy per unit volume of solder interface. The study also said that the addition of dopants minimises the amount of heat required for solder melting.

2.1.4 The effect of GNSs and Ni-GNSs on the melting temperature of Sn-3.5Ag-0.7Cu

Table 2: Melting temperature of Sn-3.5Ag-0.7Cu with 0.05 wt.%, 0.1 wt.%, 0.2 w.% of GNSs and 0.2 wt.% of Ni-GNSs (Khodabakhshi et al., 2017).

Materials	Melting Temperature (°C)
Sn-3.5Ag-0.7Cu	219.22
Sn-3.5Ag-0.7Cu/0.05GNSs	222.69
Sn-3.5Ag-0.7Cu/0.1GNSs	223.75
Sn-3.5Ag-0.7Cu/0.2GNSs	226.95
Sn-3.5Ag-0.7Cu/0.2Ni-GNSs	224.08