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APPLICATION OF HIGH TEMPERATURE LEAD-FREE SOLDER MATERIALS IN MEDICINE

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Abstract

With the recent rapid advances in medical technology there are a variety of intrusive procedures used in the medical industry today requiring tools, instruments, sensors and components in materials that are inert with respect to reactions with the body. More, new surgical techniques have been developed to improve the quality of operations, reduce the risk to patients and reduce the pain experienced by patients. Environmental concerns are also driving research in this area. The concern about toxicity and health hazards means that there is a drive to develop and use lead-free solders. Therefore, the application of high temperature lead-free solders in medicine is presented in this paper.
Keywords: lead-free alloys, high temperature solders, medicine

1. Introduction

Following the global trend and the proclaimed guidelines to administer waste materials and restrict the use of lead, the technologies for manufacturing reliable lead-free solder alloys are aggressively developing [1-4]. EU legislation, including Directive WEEE (Waste from Electrical and Electronic Equipment) and Directive RoHS (Restriction of the use of certain Hazardous Substances in electrical and electronic equipment), prohibits the use of lead containing solders in many industries starting July 1st 2006 [1,2]. The materials for high temperature soldering are among materials currently not affected by this deadline, but the pressure to remove hazardous substances will continue and spread to other, currently exempt fields [5].

A considerable amount of research has already been conducted on the formulation of new Pb-free soldering materials, not only in Europe [6], but also in the USA and Japan [2-4]. A number of promising lead-free materials (Table 1 [7]), SnAgCu-alloys i.e., have been developed as replacement for the (near-) eutectic Sn-Pb solders in mainstream applications, despite the fact that there is still no 'drop-in' alternative for the traditional Pb-Sn alloy.

Table 1.Review on different recently developed and/or manufactured LFS alloys [7]

Alloy category	Composition	Solidus (°C)	Liquidus (°C)	Note	Density	Manufacturer or investigator
Sn-Pb	63Sn-37Pb	183	183	Eutectic	8.40	(Control)
Au-Sn	80Au-20Sn	280	280	Eutectic	14.51	
Bi-Cd	60Bi-40Cd	144	144	Eutectic	9.31	Indium
Bi-In	67Bi-33In	109	109	Eutectic	8.81	Indium
Bi-In-Sn	57Bi-26In-17Sn	79	79	Eutectic		
Bi-Sn	58Bi-42Sn	138	138	Eutectic	8.56	
	95Bi-5Sn	134	251		9.64	Indium
Bi-Sn-Fe	54.5Bi-43Sn-2.5Fe		137			AT&T
Bi-Sn-In	56Bi-42Sn-2In		138			IBM
Bi-Sb	95Bi-5Sb	~275	~308			Ford
In-Ag	97In-3Ag	143	143	Eutectic	7.38	Indium
	90In-10Ag	141	237		7.54	Indium
In-Bi-Sn	48.8In-31.6Bi-19.6Sn	59	59	Eutectic?		
	51.0In-32.5Bi-16.5Sn	60	60	Eutectic	7.88	Indium
In-Sn	60In-40Sn	118	~127			
	52In-48Sn	118	118	Eutectic	7.30	Indium
	50In-50Sn	118	125		7.30	Indium
Sn	100Sn	232	232		7.28	Indium
Sn-Ag	96.5Sn-3.5Ag	221	221	Eutectic	7.36	Indium
	95Sn-5Ag	221	~250			
Sn-Ag-Cu	93.6Sn-4.7Ag-1.7Cu	216	216	Eutectic		Iowa State U
Sn-Ag-Cu-Sb	96.2Sn-2.5Ag-0.8Cu-0.5Sb	210	217			AIM (CASTIN)
Sn-Ag-Sb	65Sn-25Ag-10Sb		233			Motorola
Sn-Ag-Zn	95.5Sn-3.5Ag-1.0Zn		217			AT&T
Sn-Ag-Zn-Cu	95Sn-3.5Ag-1.0Zn-0.5Cu					AT&T
Sn-Bi-Ag	91.8Sn-4.8Bi-3.4Ag		211			Sandia
Sn-Bi-Ag-Cu	91.0Sn-4.5Bi-3.5Ag-1.0Cu		210			Senju
Sn-Bi-Cu-Ag	48Sn-46Bi-4Cu-2Ag					IBM
Sn-Bi-Cu-Ag-P	Bi 0.08-20%, Cu 0.02-1.5, Ag 0.01-1.5, P 0-0.20, rare earth mixture 0-0.20. balance Sn					Cookson
Sn-Cd	67.8Sn-32.2Cd	177	177	Eutectic	7.68	Indium
Sn-Cu	99.3Sn-0.7Cu	227	227			
	99Sn-1Cu	227	227	Eutectic		
	97Sn-3Cu	227	~330			Ford
Sn-Cu-Ag	95.5Sn-4Cu-0.5Ag	225	349 (260)			Engelhard (Silvabrite 100)
Sn-Cu-Sb-Ag	95.5Sn-3Cu-1Sb-0.5Ag		256			Motorola
Sn-In	70Sn-30In	120	~175			
	58Sn-42In	118	145		7.30	Indium
Sn-In-Ag	77.2Sn-20.0In-2.8Ag	175	187		7.25	Indium
Sn-In-Ag-Sb	88.5Sn-10.0In-1.0Ag-0.5Sb		211			Qualitek
Sn-In-Bi	90Sn-8In-2Bi					IBM
	80Sn-10In-10Bi	153	199			IBM
Sn-In-Bi-Ag	78.4Sn-9.8In-9.8Bi-2Ag					
	80Sn-10In-9.5Bi-0.5Ag	179	201			Ford
Sn-Sb	95Sn-5Sb	~234	240			Motorola
Sn-Sb-Bi-Ag	Sn approx 90-95%. Sb 3-5%, Bi 1-4.5, Ag 0.1-0.5					Willard Industries
Sn-Zn	91Sn-9Zn	199	199	Eutectic	7.27	Indium
Sn-Zn-In	87Sn-8Zn-5In	175	188			AT&T
Sn-Zn-In-Ag	87Sn-8Zn-5In-0.1Ag					AT&T

However, research is seriously lacking into high-temperature, high-Pb containing alloys, where the lead levels can be in the region above 85%, and this is reflected in the fact that these materials are, at present, exempt from the new RoHS legislation [1,2].

The single most important technological issue that companies changing over to lead-free soldering will have to address is the need for higher process temperatures to provide an effective solder joint. Higher process temperatures will impact existing soldering technology in three key areas [8]: (i) materials stability/reliability, (ii) equipment, and (iii) higher energy costs, while another important technological issue will be the compatibility of fluxes, board finishes and component finishes with lead-free solders. Current activities relating to lead-free soldering [8] are summarised in Fig.1.

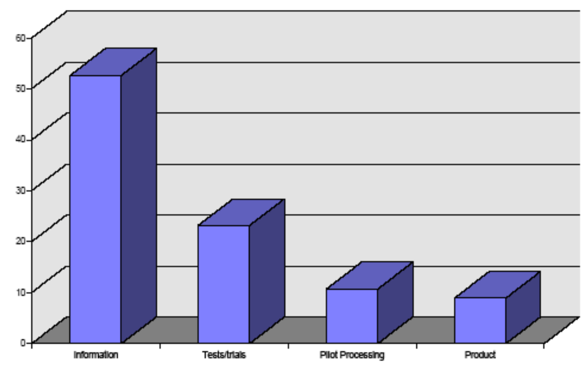

Fig.1. Current activities in lead-free soldering [8]

2. High temperature lead-free solder materials in medicine

Different researches have been done in order to develop high temperature lead-free solder materials for use in medicine, and a lot of work was performed in different fields [9-15].

So, the effect of soldering on metal-porcelain bond strength, in repaired porcelain-fused-to-metal castings, was investigated [9]; a comparative study of laser-welded vs. soldered nonprecious alloy dental bridges was given in [10]; and a comparison of the load at failure of soldered and nonsoldered porcelainfused-to-metal crowns was presented in [11].

Corrosion properties of soldered joints - corrosion pattern of dental solder and dental nickel-chromium alloy, were investigated and research on the effect of soldering alloys on metal-ceramic bond strength and mechanical properties of precious, semiprecious, and base alloys gave interesting information on the behavior of soldered restorations [12]. Namely, the presence of an intermediate layer of soldering alloy did not affect the metal-ceramic bond strength significantly. More, soldering of beta–titanium orthodontic wire by infrared radiation may be acceptable for clinical use, since Micro-XRD spectra revealed that specimens soldered with both the silver-based and titanium-based solders largely retained the bcc beta–titanium structure [13].

The effect of soldering on the metal-ceramic bond strength of an Ni-Cr base alloy was researched [14], as well as an optimal soldering system for a titanium prosthesis which has become increasingly important with the successful introduction of titanium and titanium alloys to dentistry. This studies examined the phase equilibria of Ti-Al-V system and effect of corrosion on the strength of the soldered joints of pure Ti and Ti-6AI-4V alloys joined using various solders, respectively [15,16].

Correction of deformational auricular anomalies by moulding using a simple splint consisting of a lead-free soldering wire (Fig.2) and an 8 French suction catheter was shown in [17]. The length of this device is dependent on the extent of the auricular deformity being corrected, a short splint being used to correct a localised deformity, and a longer splint required for a more extensive anomaly.

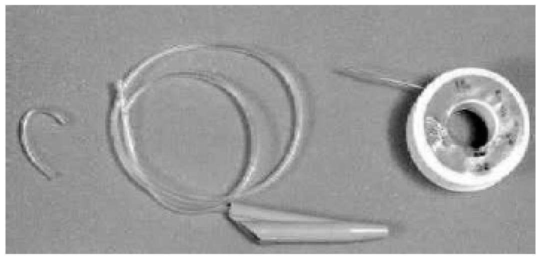

Fig. 2 A simple splint consisting of a lead-free soldering wire and an 8 French suction catheter used for correction of deformational auricular anomalies[17]

Lead-free solder materials are used in the joining of bracket on a mouth brace, too [18], as shown in Fig.3. It involves an aluminum oxide stainless steel brazed connection. Silver-based alloys are mostly used for this purpose. Its main constituents are silver and titanium, while the other constituents present in lower extents are aluminum, cadmium, bismuth, phosphorous and silicon.

Fig.3. LFS used for the joining of bracket on a mouth brace [18]

Testing the possibility of using high temperature solder materials based on Pt for application in medicine, as well as interconnections of platinum stimulating electrodes and sensors tested in physiological media were also the subject of some recent investigations [19,20].

The different instruments used in surgery are also an important example of application of brazing [18]. Various surgical instruments, such as scissors, forceps, knives, scalpels, dissecting pins, cell scraper, etc. (Fig.4) are manufactures using the brazing process. Most of these instruments are made of different types of steel, such as stainless steel, carbide steel, mild steel, etc.

Fig.4. Medical device containing electronic components [20]

Since most of the surgical instruments are made of some kind of steel, silver lead-free alloys are most suitable for them. Silver is the primary constituent element in these alloys and occupy more then 60% by weight. Copper is the second main constituent element after silver, occupying almost 25% by weight. Other important constituents are manganese, nickel, and indium. Smaller amounts of aluminum, bismuth, cadmium, phosphorous, lead, and tin are also present [18].

3. Future tendencies

The most controversial issue related to the RoHS directive is the decision to ban lead in solders used for printed circuit boards (PCBs), since all available scientific evidence indicates that the lead used in printed circuit board manufacturing and electronic assembly produces no significant environmental or health hazards. Driven by legislation, as well as by market forces (the desire to claim that a product or system is 'environmentally friendly'), the microelectronics manufacturing is shifted from the use of familiar lead-based solders to the use of lead-free solders, which created significant problems for the designers and assemblers of medical electronics systems.Although medical devices that are implanted, such as that shown in Fig.4, are currently not covered under WEEE or RoHS [1], it is expected that this will change as the reliability of lead-free soldered connections is developed [21].

According to the estimations [22], the medical electronic systems using lead-free solders must reach the levels of reliability of conventional lead-based solders within a few years. The transition will have a price, but much of the cost will relate to labour and reliability rather than materials. Lead-free solders themselves will probably cost more than lead-based solders - probably three to five times as much [22] - but will have relatively little impact on overall costs because of the small quantities used. The impact will be greater in wave soldering, where larger quantities of solder are needed. Higher-temperature moulding compounds may also be slightly more expensive than conventional varieties. As is the case for any manufacturing practice, careful planning and execution will be the keys to making the transition in a timely and efficient manner [23].

4. Conclusion

Recent development in medical technology requires different tools, instruments, sensors and components inert with respect to reactions with the body. Also, environmental concerns drive advanced research in this area demanding new specific materials. Lead-free solder materials are among them, and their further research and application should significantly improve the quality of medical treatment and its environmental effect.

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