Environment Compatibility Technology for Servo Systems

Norio Arai Syusaku Magotake

1. Introduction

Having become CF-free in May 1993, Sanyo Denki then came up with "Lead-Free soldering technology" as the next target in our efforts to establish environment compatibility technology.

The Environment Control Committee's Chemical Substances Emission Control Sub committee, which was brought into existence April 2000, approved the "Lead-Free soldering technology" officially as an issue to be addressed when we started working toward establishing such a technology.

This article describes the "Lead-Free soldering technology" we are currently working on with a great emphasis as an example of the environment compatibility technology for servo systems.

2. Trend for Lead-Free Soldering

2.1 Why Lead-Free Soldering?

"Solder" used on electrical/electronic products is said to be harmful to human bodies in the following way.
Electric/electronic products disposed of and buried at the end of their service life
→ Acid rain increased due to polluted atmosphere
→ "Lead," which accounts for 37% of solder, diffuses into acid rain
→ Lead pollutes ground water and rivers/lakes
→ Lead in the food chain or drinking water finds its way into the human body → Builds up in the human bodies
→ Lead damages human organs (Lowered IQ, etc.)

Following is the description of the action being taken to regulate the Lead used for electric/electronic products to reduce the Lead's hazardous effects.

2.2 Worldwide Trend to Control Lead Contained in Solder

The actions being taken by public organizations to control Lead contained in solder are as follows:

2.2.1 EU

The EU directive on waste electrical/electronic equipment (WEEE Note (1))
⇒ Jan. 2006 The use of Lead in electronic equipment will be banned (draft).
··· At the final voting at EU Parliament the directive is expected to take effect in 2002.

2.2.2 USA

A bill to ban the use of solder containing 0.1% or more of Lead (exempting the electronic equipment industry) was tabled but failed to be written into law in 1990. Since then no action has been taken to control the use of solder.

But in response to the action being taken in Europe and Japan, NEMI Task Force (Note 2) is developing Lead-Free mounting technology in order to introduce the total ban on the use of Lead in 2004.

2.2.3 Japan

Amendment to the directive on the disposal of waste materials in June 1998
⇒ Restriction was imposed on disposal of Lead-containing waste materials at disposal site
Consumer Electronic Product Recycle Act came into effect in April 2001.
⇒ Control on waste Lead was tightened

2.3 Major Manufacturers' Schedule for Transition to Lead-Free Production

Table 1 is the major manufacturers' schedule for Transition to Lead-Free Production.

The typical schedule for transition to the complete Lead-Free soldering is as follows:

(1) 1st step
Solder used in all in-house manufacturing processes will be Lead-Free
→ By April 2002 to March, 2003
(2) 2nd step
Leads (plated electrodes) on purchased parts will be Lead-Free
(3) 3rd step
Solder used inside purchased parts will be Lead-Free
→ By January 2004

2.4 Sanyo Denki's Schedule for Transition to Lead-Free Production

In step with the worldwide approach toward Lead regulation, and major manufacturers' schedule for Transition to Lead-Free Production, Sanyo Denki drew up its own schedule in January 2000 and finalized it in April 2000.

(1) 1st step
Solder used in all in-house manufacturing processes will be Lead-Free
→ To be implemented for the soldering process to be launched in April 2002.
(2) 2nd step
All purchased parts (plated electrodes and internal soldering) will be Lead-Free
→ Target is to have more than 95% of purchased parts Lead-Free by January 2004

Table 1 Major Manufacturers' Schedule for Transition to Lead-Free Production [1]

Manufacturer	Applicable product/policy	2001				2002				2003				2004	
		January	April	July	October	January	April	July	October	January	April	July	October	January	April
Matsushita Electronics Group	MD player	Jan. 1998													
	VTR deck	Dec. 1999													
	Panasert	Dec. 2000													
	Total ban within Matsushita Group (including purchased parts)									→					
Hitachi Group	Some VCRs and refrigerators	Jan. 1999													
	Notebook PC	2000 -													
	Total ban within Hitachi (except purchased parts and those produced overseas)									→					
	Total ban within Hitachi group													→	
NEC	Beeper	Dec. 1998													
	Notebook PC	Jan. 1999													
	To be reduced 50% as compared to 1997	→													
	Total ban								→						
SONY	VCR	Mar. 2000													
	TV, Notebook PC	Jan. 2000													
	Total ban (including those produced and purchaded in Japan)					→									
	Total ban (including those produced overseas)									→					
Mitsubishi Electric	To be reduced 50% (in 4 consumer electronic products)														2004
	Total ban														2005
Fujitsu	PWBs to be reduced by half				→										
	Total ban								→						
SEIKO EPSON	Total ban (except for soldering inside components)					→									
Nissan Motors	Keyless entry	Aug. 2000													
Murata Seisakusho	Component elecytrode								→						
	Soldering inside components											→			

Table 2 Composition and Properties of Various Types of Lead-Free Solder [2]

Alloy Composition	Solid phase - Liquid phase (℃)	Properties	Cost Ratio	Adopted by	Applicable Products
63Sn-37Pb	183	Conventional symbiosis solder containing Lead	Baee = 1.0		
Sn-0.7Cu-0.3Ag	217-227	For flow. Cost-oriented with low Ag composition ratio (Senju Model No. M35)	1.4	-	-
Sn-0.7Cu-Ni(trace)	217-227	For flow. Half the cost of Sn/Ag based solder. Jointly developed with Nippon Superior	1.2	Matsushita Electric Industries	Stationary-type VTR Atmospheric flow
Sn-1.5Ag-5Cu-1Bi	201-218	For reflow. As reliable as conventional type	1.9	Sharp	-
Sn-2.5Ag-0.8Cu-0.5Sb	213-218	With 4 components, composition is hard to control	1.8	-	-
Sn-2.5Ag-1Bi-0.5Cu	214-223	Dubbed SONY alloy. SONY to switch to Sn-3.0Ag-0.5Cu as of May,2001	1.9	SONY	Digital camcorder Notebook PC
Sn-2.8Ag-15Bi	193-203	Low temperature range. Actual soldering temperature 100℃ or less	1.9	Hitachi	Large computer module
Sn-2.8Ag-20In	179-189	Unstable In supply and high cost	7.6	-	-
Sn-2Ag-0.7Cu-3Bi	205-218	With 4 components, composition is hard to control	1.8	Fujitsu, NEC	
Sn-2Ag-3Bi	205-218	Narrow temperature tolerance range despite low melting point. Poor wettability. For reflow	1.8	Matsushita Electric Industry	MD player
Sn-3.0Ag-0.5Cu	217-219	For reflow/manual soldering (Recommended by JEIDA, Senju Model No. M705/measures for patent application)	2.0	Matsushita, SEIKO Epson, SONY, NEC, and more	
Sn-3.5(3-5)Ag-0.75(0.5-3)Cu	217-219	Good heat fatigue resistance. Jointly developed by Senju and Matsushita/Patent scope overlapping that by Iowa University	2.1	Matsushita, Nissan	Keyless entry
Sn-3.5Ag	221	Standard provided in "JIS Z 3282 Solder", Eutectec solder	2.1	-	
Sn-3.5Ag-0.75Cu	217-219	Reflow/flow/manual soldering all OK. Tends to cause dross	2.1	NEC	Mobile terminal
Sn-3.5Ag-1.1Cu	216	For reflow	2.1	Sharp	-
Sn-3.5Ag-1.5In	218	Unstable In supply	2.4	-	-
Sn-3.5Ag-4.8Bi	205-210	Tends to cause lift-off	2.5	-	-
Sn--3Ag-0.7Cu	217-219	High melting point type, more reliable than conventional type	2.0	Hitachi	vacuum cleaner washing machine
Sn-3Ag-10Bi	178-212	For reflow	1.9	Sharp	
Sn-58Bi	139	Standard provided in "JIS Z 3282 Solder", Eutectec solder, low melting point type	1.4	Fujitsu	
Sn-5Sb	235-240	Standard provided in "JIS Z 3282 Solder"	1.2	-	
Sn-5Zn-10Bi	168-190	Poor wettability	1.2	-	
Sn-7.5Bi-2Ag-0.5Cu	213-218	Alloy H, basic Lead-free solder	1.8	-	
Sn-8Zn-3Bi	186-197	Melting point close to that of conventional symbiosis types, supplied by Showa Denko	1.6	NEC(Nigata), Fujitsu, Sharp, JVC	Digital camcorder, Notebook PC
Sn-9Zn	199	Poor wettability. For N2 reflow	1.2	Toshiba	-

Note (1) WEEE: Directive on Waste from Electrical and Electronic Equipment

Note (2) NEMI: The National Electronics Manufacturing Initiative

3. Types and Trend of Lead-Free Solder Alloy

3.1 Types of Lead-Free Solder and Their Advantages/Disadvantages

Table 2 above lists the solder alloy compositions, and the properties of each Lead-Free solder alloy. Except for some conventionally used high-temperature or low-temperature Lead-Free soldering materials, nothing has yet been standardized about Lead-Free soldering.

Table 3 summarizes the types of Lead-Free solder and their advantages and disadvantages as published by various Lead-Free projects or research organizations.

3.2 Trends of Lead-Free Solder Alloys

The alloy compositions of Lead-Free solder recommended by the institutions in industrial countries are shown in Table 4. Sn-Ag-Cu based alloys are now becoming dominant as soldering does not weaken the boundary surfaces even if the component is plated with 63Sn-37Pb (Lead-carrying eutectic solder).

Table 3 Types of Lead-Free Solder and Their Advantages and Disadvantages

Category	Alloy type (typical)	Advantage	Disadvantage
Sn-Ag(-Cu) base	Sn-3.0Ag-0.5Cu	1.JEIDA-recommended with abundant reliability data. Adopted by most major electric manufacturers 2. Component plated with Sn-Pb solder causes no problem (useful during transition to Lead-Free soldering) 3. Exhibits better basic alloy strength against creep or temperature cycle than Lead-containing eutectic solder.	1. Caution is needed against the component temperature exceeding what it can withstand.(Melting point is 36℃higher than that of eutectic solder.) Reflow: 230℃ Peak -> 250 to 260℃ peak is required. 2. High Ag composition ratio pushes up the cost of materials (more than 2 folds) 3. Flow: Some lift-off occurs due to the combination with Sn-Pb-plated component. 4. Somewhat poorer wettability than eutectic Lead-containing solder
	Sn-3.5Ag	Same as 2, and 3 above	
	Sn-(2～4)Ag - (1～6) Bi - (1～3) In	1. With melting point close to that of Lead-containing eutectic solder, the component solder temperature does not exceed what it can withstand. 2. Economical with regard to solder containing less Ag	1. Reflow: Surface strength will be reduced if Lead from the component -plating gets into solder that contains more than 4% of Bi. 2. Flow: Solder containing Bi more than 3% causes frequent lift-off on a throughhole PWB if used with Sn-Pb plated components
Sn-Cu base	Sn-0.7Cu-0.3Ag	Flow: With low Ag composition ratio, it is advantageous cost-wise (suitable flow solder tank)	1. Caution is needed against the component temperature exceeding what it can withstand.(Melting point is 44℃ higher than that of eutectic solder.) 2. Flow: Some lift-off occurs due to the combination with Sn-Pb-plated component. 3. Dross occurs more frequently than with Sn-3.0Ag-0.5Cu 4. Poor throughhole wetting than with Sn-3.0Ag-0.5Cu
	Sn-0.7Cu + trace of Ni (Au, In, Ge)		
Sn-Zn base	Sn-9Zn	1. Advantageous cost-wise (on par with Sn-Cu based solder) 2. With melting point 198℃ close to that of Lead-containing eutectic solder, the component solder temperature does not exceed what it can withstand.	1. Caution is necessary in handing because it is so easy to become oxidized 2. Corrosive (especially when exposed to Cl) 3. Reflow: Poor printability
	Sn-8Zn-3Bi		
Sn-Bi base	Sn-57Bi-1Ag	Lower melting point than that of eutectic solder	1. Affinity with Sn-Pb plated component (weakened boundary surfaces, lift-off) is similar to that of Sn-Ag-Bi-In solder. 2. Joint strength is not as good as that with other types. 3. Bi is rare resource.
	Sn-58Bi		

Table 4 Compositions of Lead-Free Solder Recommended by Institutions in Industrial Countries

Country	Institution (Project) name	Recommended Composition	Applicable soldering		
			Reflow	Flow	Manual
EU	IDEALS	Sn-3.8Ag-0.7Cu	○		
	SOLDERTEC	Sn-(3.4-4.1)Ag-(0.45-0.9)Cu	○	○	○
USA	NEMI	Sn-3.9Ag-0.6Cu	○		
Japan	JEIDA	Sn-3.0Ag-0.5Cu	○	○	

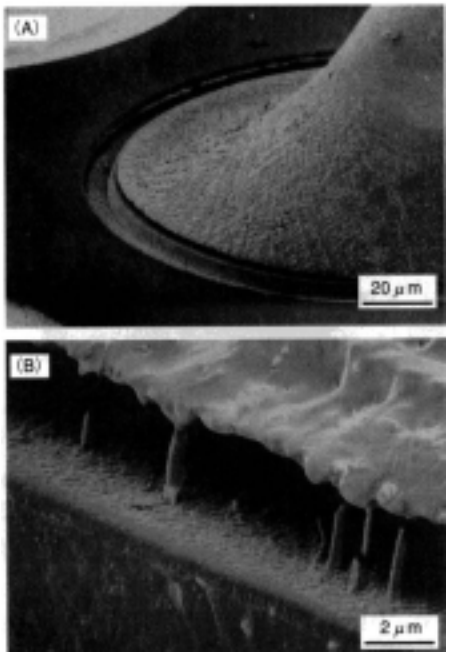

Fig. 1 Lift-off[3]

Note (3) Lift-off: Occurs with flow soldering process. It is a phenomenon that occurs on boundary surfaces between the copper film land and the fillet on a through-hole PWB where boundary surfaces become separated . (See Fig. 1)

4. Sanyo Denki's Policy for Switching to Lead-Free Soldering

4.1 Selecting Lead-Free Solder Materials

Taking into consideration the compositions and properties of the various types of Lead-Free solder, Sanyo Denki has selected the solder materials as shown in Table 5 and is currently experimenting with them to find the soldering processes to be adopted.

Table 5 Applicable Products and Soldering Materials and Processes

Applicable product	Soldering material/Process		
	Cream solder	Flow solder	Resin solder
Fan motor	Solder alloy: Sn-3.0Ag-0.5Cu Flux class: RMA Atmospheric flow	Solder alloy: Sn-3.0Ag-0.5Cu (Or Sn-0.7Cu-0.3Ag) Flux class: RA or higher Atmospheric reflow	Solder alloy: Sn-3.0Ag-0.5Cu Flux class: JIS A class or higher Resin content: P3
Stepping motor	—		
Sensor	Solder alloy: Sn-3.0Ag-0.5Cu Flux class: RMA Low residue Atmospheric flow (Or N flow)	Solder alloy: Sn-3.0Ag-0.5Cu Flux class: RMA Atmospheric flow (Or N flow)	Solder alloy: Sn-3.0Ag-0.5Cu Flux class: RMA Resin contained: F3
Servo amplifier			
Stepping motor driver			
UPS			

4.2 Current Problems and Approaches

The technical problems we are currently facing and the measures we intend to take are as follows:

(1) Atmospheric flow soldering causes frequent dross and bridges. → Searching for new flux and N2 flow soldering.

(2) With the existing reflow oven, the reflow zone temperature profile exceeds the temperature that heat-sensitive components such as chip-type aluminum electrolyte capacitors can withstand. → Considering the use of a reflow oven with more zones in it.

(3) The residual film after reflow is hard to peel off from the PWB that is coated for servo amps. Cream solder using highly reliable flux is hard to find. → Searching for new cream solder.

(4) Lead-Free solder has poorer wettability compared to eutectic solder containing Lead. → Choosing appropriate cream solder and/or flux and considering the use of N2 reflow/flow.

5. Conclusion

We have described the "Lead-Free soldering technology" we are currently working on as an example of Enviroment Compatibility technology for servo systems. With the target date set for April next year for launching mass production, we are at a critical point of trying to establish the technology. Although many problems still remain to be solved, we, the "Lead-Free soldering working group" and the Division are firmly determined to put all our resources together in addressing each of these issues.

References

(1) Nikkei Board Guide '99 Winter issue, Nikkei Sangyo News Paper July 3 '98, and many websites
(2) Nikkei Electronics, Dec.4 2000, p.152, 155, etc.
(3) "Lead-Free Soldering Technology" p. 122 (by Tadatomo Suga), Nikkan Kogyo Newspaper (1999)

Norio Arai
Joined company in 1983
Servo Systems Division, 2nd Designing Section
Worked on servo amp engineering covering all aspects

Syusaku Magotake
Joined company in 1996
Servo Systems Division, 2nd Production of Engineering Section
Worked on the development of servo amp mounting technology