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Restricted Substances and Lead-free Soldering

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Introduction

Due to increasing environmental concerns a number of restrictions have been placed on the material content of electronic components and electronic assemblies. The main environmental concern is that the large quantities of obsolete electronic goods are being disposed of via land-fill. Over time the materials used in these assemblies enter the water within the ground thus contaminating neighbouring water systems.

A number of environmental directives are being issued by the European Union in order to address some of these issues.

End-of Life Vehicle (ELV) Directive – which aims to ensure manufacturers of vehicles will establish methods of recycling vehicles and also restricts certain substances from being used in vehicle manufacture.

Waste Electrical and Electronic Equipment (WEEE) Directive – requires manufacturers of electronic and electrical goods to establish methods of recycling these goods, it also restricts certain substances being used as defined in the **RoHS Directive**. The directive does not cover all electrical goods e.g. military products and aerospace are not included.

Restriction on Hazardous Substances (RoHS) Directive – Defines the substances prohibited in electrical and electronic goods covered by the **WEEE directive**.

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End-of Life Vehicle (ELV) Directive

This directive states that vehicles placed on the European market after 1 July 2003 do not contain:

Lead
Cadmium
Mercury
Hexavalent Chromium

However there are exemptions, which include:

Electrical components which contain lead in glass or ceramics matrix compound.
Solder in printed circuit boards and other applications.

This means that there is no requirement for lead-free soldering for vehicles, nor for capacitors to be lead-free. However Cadmium was/is commonly used as part of ceramic

dielectrics and as the glass system in termination pastes for ceramic components and it should be clearly established that parts are Cadmium free for these applications.

Syfer has been working towards the elimination of Cadmium in all its product of the past 4 years as part of the Environmental Management System ISO 14001. All Syfer products are Cadmium free.

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Restriction on Hazardous Substances (RoHS) Directive

The Directive states:

"By 1 July 2006 at the latest, Member States shall ensure that new electrical and electronic equipment put on the market does not contain

Lead
Mercury
Cadmium
Hexavalent Chromium
Polybrominated biphenyls (PBB)
Polbrominated diphenyl ether (PBDE)"

The latter two compounds are flame retardants used generally in plastics.

This directive gives rise to the **lead-free** requirement which has become the dominant issue as it effectively bans the use of Tin/Lead solders which are used on virtually 100% of PCB assembly lines.

As far as the supply of components is concerned there are two issues resulting:

- Do the components contain the banned materials?
- Are the components capable of being soldered using lead-free solders?

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Material content in Syfer Capacitors

The RoHS directive includes a list of exemptions and these include:

- Lead in glass of cathode ray tubes, electronic components and fluorescent tubes. (Note: this means lead in the form of **glass** in electronic components)

- Lead in high melting temperature type solders (i.e. tin/lead solders containing more than 85% lead)
- Lead in electronic ceramic parts (e.g. piezoelectric devices)

Ceramic capacitors typically use lead in a glass form both in the dielectric and end termination and as this is in a glass form it is allowed under the RoHS Directive. The solder finish on Syfer surface mount capacitors is 100% tin and is compatible with either tin/lead or lead-free soldering operations.

Syfer surface mount capacitors comply with the requirements of the RoHS directive.

The Syfer radial range and other specialist assemblies generally use lead-free solders in the internal construction. Due to the fact that the soldering temperature for lead-free alloys used in PCB assembly will be higher than currently used, solder containing more than 85% lead may have to be used in the component construction.

However many of the current applications for these products are avionic or military and we may be required to maintain the existing construction for reliability reasons.

If you are planning to use radial product or any specialist assembly in a lead-free application we would recommend contacting our sales office to ensure our part can meet your requirements.

Details of the material content for Syfer surface mount capacitors can be found in the following appendices:

Summary of material content by dielectric

Appendix 1 Low Value C0G
Appendix 2 Mid Value C0G
Appendix 3 High Value C0G
Appendix 4 Low Value X7R
Appendix 5 Mid Value X7R
Appendix 6 High value X7R

Note that some of the dielectrics do not contain lead – low value C0G, mid value X7R, and high value X7R. These can be terminated with a polymer termination known as: FlexiCap™

This polymer is lead-free and therefore certain ranges of surface mount capacitors can be provided entirely lead-free.

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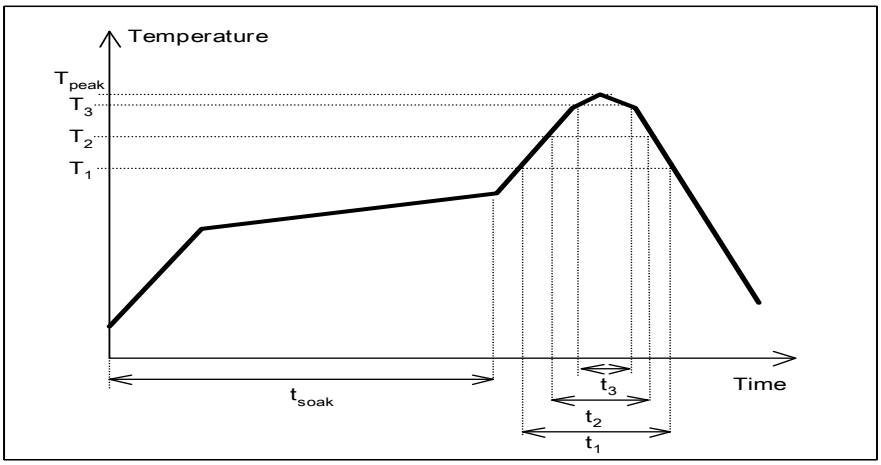
Lead-Free Soldering

In order to comply with the lead-free aspect of the final product, most PCB assemblies will be forced to switch to a lead-free alloy the most common by far being a high Tin alloy with small amounts of Silver and Copper - Sn /Ag(3.0-4.0)/Cu(0.5-0.9).

This will require higher soldering temperatures due to the higher melting point of the alloy. A typical maximum heat exposure profile for reflow is shown:

Pb-free reflow profile requirements for soldering heat resistance		
Parameter	**Reference**	**Specification**
Average temperature gradient in preheating		2.5℃/s
Soak time	t_{soak}	2-3 minutes
Time above 217℃	t_1	Max 60 s
Time above 230℃	t_2	Max 50 s
Time above 250℃	t_3	Max 10 s
Peak temperature in reflow	T_{peak}	260℃
Temperature gradient in cooling		Max -6℃/s



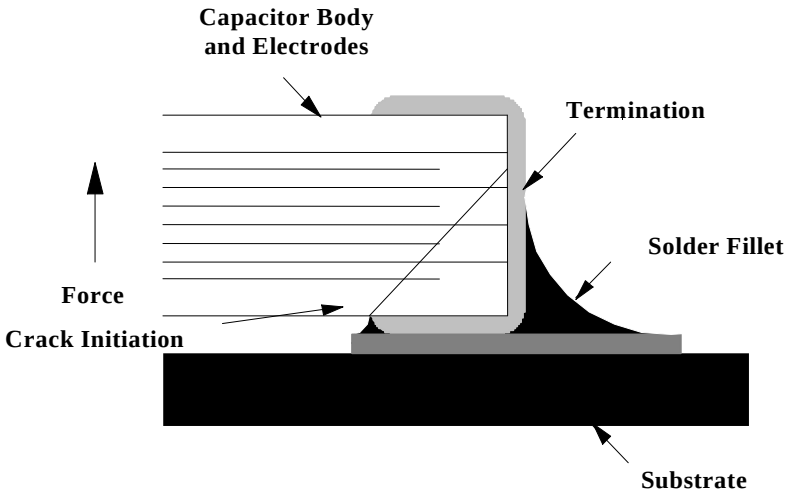
Syfer surface mount capacitors can all withstand this profile and operate satisfactorily. For our radial range and any specialty product please consult our sales department.

One of the issues with using high tin content solder is that the solder is harder and stronger. There has been much testing performed on lead-free solder joints particularly with regard to temperature cycling and the onset of fatigue fractures. Generally lead-free being better in the range –40°C to 100°C and much poorer when tested over –55 °C to 125/160°C. Few of these tests reflect the increased stress transferred to the actual components and also the risk of mechanically cracking due to PCB flexing as result of the these comparatively hard and strong solder joints.

Unsupported PCBs will also flex more at the higher soldering temperatures and may apply additional stress, increasing the chance of mechanical cracking.

Syfer has undertaken a range of tests and generally would recommend the use of polymer termination FlexiCap™ for case sizes greater than 1206 in order reduce the amount of stress transferred to the ceramic capacitor itself.

Example of mechanical cracking



Example of capacitor issued by customers to Syfer for failure investigation:

Yellow potting compound

Electrodes

Standard termination material (not polymer)

Mechanical crack (caused capacitor failure)

Black areas are damaged sections within the capacitor caused during the electrical failure

White lines are thermal cracks created during the electrical failure

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Information is also available on Syfer's web site www.syfer.com

Appendix 1
Low Value C0G

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	Low value COG		Typical Component Composition
	Ba	7440-39-3		%	60-75% Ceramic
	Ti	7440-32-6	17.5	%	
	Nd	7440-00-8		%	
	Bi	7440-69-9		%	
	Pb	7439-92-1		%	
	Co	7440-48-4	0.3	%	
	Zn	7440-66-6	7.5	%	
	Si	7440-21-3	8	%	
	Al	7429-90-5	8	%	
	B	7440-42-8	3	%	
	Mg	7439-95-4	17.5	%	
	Mn	7439-96-5		%	
	Zr	7440-67-7		%	
	Sn	7440-31-5		%	
	Nb	7440-03-1		%	
	Other primarily O		38.2	%	
Electrode					3-8% Electrode
	Ag	7440-22-4	75	%	
	Pd	7440-05-3	25	%	
Termination					17-30% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					3-5% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric

Appendix 2
Mid Value C0G

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	Mid value COG		Typical Component Composition
	Ba	7440-39-3	15	%	70-85% Ceramic
	Ti	7440-32-6	25	%	
	Nd	7440-00-8	25	%	
	Bi	7440-69-9	7.5	%	
	Pb	7439-92-1	1.5	%	
	Co	7440-48-4	0.3	%	
	Zn	7440-66-6	0.8	%	
	Si	7440-21-3	0.3	%	
	Al	7429-90-5		%	
	B	7440-42-8	0.5	%	
	Mg	7439-95-4		%	
	Mn	7439-96-5	0.1	%	
	Zr	7440-67-7		%	
	Sn	7440-31-5		%	
	Nb	7440-03-1		%	
	Other primarily O		24	%	
Electrode					3-7% Electrode
	Ag	7440-22-4	75	%	
	Pd	7440-05-3	25	%	
Termination					8-20% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					1-3% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric

Appendix 3
High Value C0G

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	High value COG		Typical Component Composition
	Ba	7440-39-3	15	%	65-80% Ceramic
	Ti	7440-32-6	20	%	
	Nd	7440-00-8	25	%	
	Bi	7440-69-9	10	%	
	Pb	7439-92-1	3	%	
	Co	7440-48-4		%	
	Zn	7440-66-6	2	%	
	Si	7440-21-3		%	
	Al	7429-90-5		%	
	B	7440-42-8		%	
	Mg	7439-95-4		%	
	Mn	7439-96-5		%	
	Zr	7440-67-7		%	
	Sn	7440-31-5	2	%	
	Nb	7440-03-1		%	
	Other primarily O		23	%	
Electrode					5-15% Electrode
	Ag	7440-22-4	90	%	
	Pd	7440-05-3	10	%	
Termination					5-17% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					1-3% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric

Appendix 4
Low Value X7R

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	Low value X7R		Typical Component Composition
	Ba	7440-39-3	55	%	75-90% Ceramic
	Ti	7440-32-6	15	%	
	Nd	7440-00-8		%	
	Bi	7440-69-9	2	%	
	Pb	7439-92-1	1.5	%	
	Co	7440-48-4	0.3	%	
	Zn	7440-66-6	0.8	%	
	Si	7440-21-3		%	
	Al	7429-90-5		%	
	B	7440-42-8	0.5	%	
	Mg	7439-95-4		%	
	Mn	7439-96-5		%	
	Zr	7440-67-7		%	
	Sn	7440-31-5		%	
	Nb	7440-03-1		%	
	Other primarily O		24.9	%	
Electrode					1-5% Electrode
	Ag	7440-22-4	75	%	
	Pd	7440-05-3	25	%	
Termination					5-17% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					1-3% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric

Appendix 5
Mid Value X7R

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	Mid value X7R		Typical Component Composition
	Ba	7440-39-3	58	%	70-85% Ceramic
	Ti	7440-32-6	20	%	
	Nd	7440-00-8	0.8	%	
	Bi	7440-69-9	0.4	%	
	Pb	7439-92-1		%	
	Co	7440-48-4		%	
	Zn	7440-66-6	0.5	%	
	Si	7440-21-3		%	
	Al	7429-90-5		%	
	B	7440-42-8		%	
	Mg	7439-95-4		%	
	Mn	7439-96-5		%	
	Zr	7440-67-7		%	
	Sn	7440-31-5		%	
	Nb	7440-03-1	0.5	%	
	Other primarily O		19.8	%	
Electrode					3-10% Electrode
	Ag	7440-22-4	85	%	
	Pd	7440-05-3	15	%	
Termination					8-20% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					1-3% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric

Appendix 6
High value X7R

Generic Component Material Declaration (all percentages are approximate)
Standard Nickel Barrier Product

Ceramic	Element	CAS Number	High value X7R		Typical Component Composition
	Ba	7440-39-3	58	%	65-80% Ceramic
	Ti	7440-32-6	20	%	
	Nd	7440-00-8	0.8	%	
	Bi	7440-69-9		%	
	Pb	7439-92-1		%	
	Co	7440-48-4		%	
	Zn	7440-66-6	0.5	%	
	Si	7440-21-3		%	
	Al	7429-90-5		%	
	B	7440-42-8		%	
	Mg	7439-95-4		%	
	Mn	7439-96-5		%	
	Zr	7440-67-7		%	
	Sn	7440-31-5		%	
	Nb	7440-03-1	0.5	%	
	Other primarily O		20.2	%	
Electrode					5-15% Electrode
	Ag	7440-22-4	70	%	
	Pd	7440-05-3	30	%	
Termination					5-17% Termination
	Ag	7440-22-4	94	%	
	Pd	7440-05-3		%	
	Pb	7439-92-1	4	%	
	Bi	7440-69-9		%	
	Other primarily O, B, Si		2	%	
Plating					1-3% Plating
	Ni	7440-02-0	31	%	
	Sn	7440-31-5	69	%	

Summary of material content by dielectric