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Lead environmental issues and new solder alloys in electro-electronics equipment

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Abstract
The use of Surface Mounted Technology (SMT) and the miniaturization of the electronics equipment are demanding new lead-free materials in the soldering process, due to its high toxicity to human being and environmental concerns. Global competitiveness has been driving industries to technological development as challenges to the manufactures and there is an effort to use alternative materials for the soldering electronic components to find an environment-friendly process. This paper presents a literature review involving soldering processes and describes the lead toxicity from related residue. The main solder alloy that is nowadays used to substitute tin-lead and European Directives are also presented.

Keywords
RoHS directive, WEEE directive, lead-free solder, electro-electronic products.

GRIGOLETTO, E. M.; PÉCORA, A. A. B. Lead environmental issues and new solder alloys in electro-electronics equipment. **Labor & Engenho**, Campinas [Brasil], v.7, n.4, p.68-74, 2013. Disponível em: <www.conpadre.org>.

Introduction

The advent of the integrated circuit and the utilization of Surface Mounted Technology (SMT) started and turned the miniaturization of electro-electronic equipment into reality SMT made possible to assembly electronic components on Printed Circuit Board (PCB) surface. Regarding the soldering process, the great diversity of electro-electronic products is demanding new materials that are lead-free in order to obtain electronic products and manufacturing processes environmentally cleaner. Modifications in the raw material as in the soldering process are currently occurring to reduce pollutant emissions (GRIGOLETTO, 2003).

The change in the solder alloy composition should present best results concerning the environmental impact when comparing tin-lead and lead-free solder alloys because the new alloys present lower toxicity than the lead ones (HWANG, 2004; GRIGOLETTO, 2003; MAESTRELLI; PFAHL, 2001).

The usual tin-lead alloy applied in electro-electronics industries is made of 63%Sn and 37%Pb. This composition has been chosen because it has a low value of the melting point temperature (183º C) and desirable mechanical, wetting and electrical properties. Furthermore, Pb is a cheap material when compared with others possible materials.

The Sn-Ag-Cu (SAC) alloy in different compositions is the most used in both wave and reflow oven equipment for soldering. Some suppliers present solder alloys recycling program. In Brazil several electro-electronic industries are using lead-free solders. The SAC alloy composition most used presents 95.5%Sn, 3.8%Ag and 0.7%Cu. This solder alloy presents a higher melting point (217º C) than the tin-lead one which is a disadvantage (ANDERSON et al., 2007).

The objective of the present paper is to show a literature review involving soldering process and lead toxicity from its residues.

RoHS and WEEE Directives

The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Directive (RoHS) (2002/95/EC) was elaborated by the European Parliament and the Council of the European Union. This directive bans the manufacturing of new electrical and electronic equipment (EEE) containing lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants. The RoHS directive is applied to equipment that was put in the market since July 1st (MAESTRELLI; GRIGOLETTO 2006).

The purpose of WEEE Directive (2002/96/EC) is the prevention of electrical and electronics equipment waste. The recycling, the reuse and other forms of recovery wastes are the objectives of WEEE Directive to reduce the disposal of such equipment. This directive also seeks to improve environmental performance of producers, distributors, consumers and those operators directly involved in the treatment of these kind of waste (MAESTRELLI; GRIGOLETTO, 2006).

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Lead as a contaminant

Lead is currently an essential widely used metal in many industrial processes. In alloys and other different compounds, lead is used in the manufacture of highly technological products. Additionally, lead is used in batteries, paints, ceramics, cables and ammunition products. Lead presents desired physical-chemical properties such as malleability, low melting point, high resistance to corrosion, high electric conductivity and long working life, which gives it advantages over other metals, making it suitable for various industrial processes (LUND, 1971).

Lead is a very important chemical element for soldering processes as it can form alloys, generally composed by two or three metals, and it acts as a surface adhesion element. According to electronic industry, apart from promoting adhesion of components to the surface of the board, lead has the function of improving the electrical link between electro-electronic components and circuits.

Residues, generated by the lead obtention and its recycling process, may be added to the environment, contaminating air, water and soil. One environmental concern is that lead particles remain from seven to thirty days in the air. Topographical and meteorological factors present great influence on how long these particles remain in the air. Rain takes lead particles from the air and promotes their introduction into the soil and water bodies (GRIFFIN; KNELSON, 1975).

Human contamination by lead can occur by ingestion of the compound in an organic or inorganic form. When ingestion occurs by organometallic derivatives, the absorption is fast. However, as soon as the exposition ceases, the levels of lead in the organism decrease quickly. On the other hand, ingestion of inorganic lead presents slow absorption and elimination by the organism (OGA, 1996).

Long-term human intoxication in industry, which frequently is verified in lead related industries, is called saturnism or plumbism. It may take years for the illness' symptoms to appear, caused by substitution, in the bones, of calcium by lead. Intoxication can occur either when a high amount of lead absorption is involved or after a long period of exposition to low concentrations of this metal (GOODMAN; GILMAN; GILMAN, 1983).

Soldering process of electronic components on surfaces (SMT)

The soldering of components SMT has been traditionally carried out with tin-lead alloys. Typically, two soldering processes are used: (i) double wave and (ii) reflow process.

Regarding the double wave process, the solder alloy of tin-lead is used in solid bars, which will be melted to solder the Surface Mounted Components (SMC) and conventional components. On the other hand, the reflow process uses solder pastes made up of tin-lead alloy dispersed in solder flux and vehicle. The alloy composition used to be 60Sn/40Pb, 63Sn/37Pb and 62Sn/36Pb/2Ag. The 63Sn/37Pb alloy is eutectic and it was widely used until 2006. (HWANG, 1989).

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Soldering process by double wave

The soldering process by double wave consists of passing the printed circuit board, containing the components, through two waves of melted alloy solder. The first wave is a turbulent flow and its function is to wet the terminals, the second one is a laminar flow and it aims at removing the possible solder excesses, which may have been deposited during the process. Soldering by double wave releases solder alloy residue and its oxides and the emissions from tin-lead alloy aerosols are liberated into the air (MEESEMAECKER; ROZUMEK; TARRIEU, 1989).

The emission of residues in the double wave soldering process could occur during the soldering of components. The volatilization of the solder flux steam and lead oxide emission into the air could cause residues in the environment. As the solder is in liquid form during soldering by double wave, a supernatant slag is produced, due to its contamination with copper, brass and other chemical elements coming from the terminals of the components. The solder used in the production of assembled boards is recycled by solder alloy producer, which commercializes it to be used again in the same soldering process. Boards, which possess minor defects, are reworked and, in this process, there is emission of solder residues into the environment. If the rework is not viable, the assembled plate is discarded. Figure 1 presents a conventional soldering scheme carried out by double wave (VELARDEZ; GRIGOLETTO, 1990).

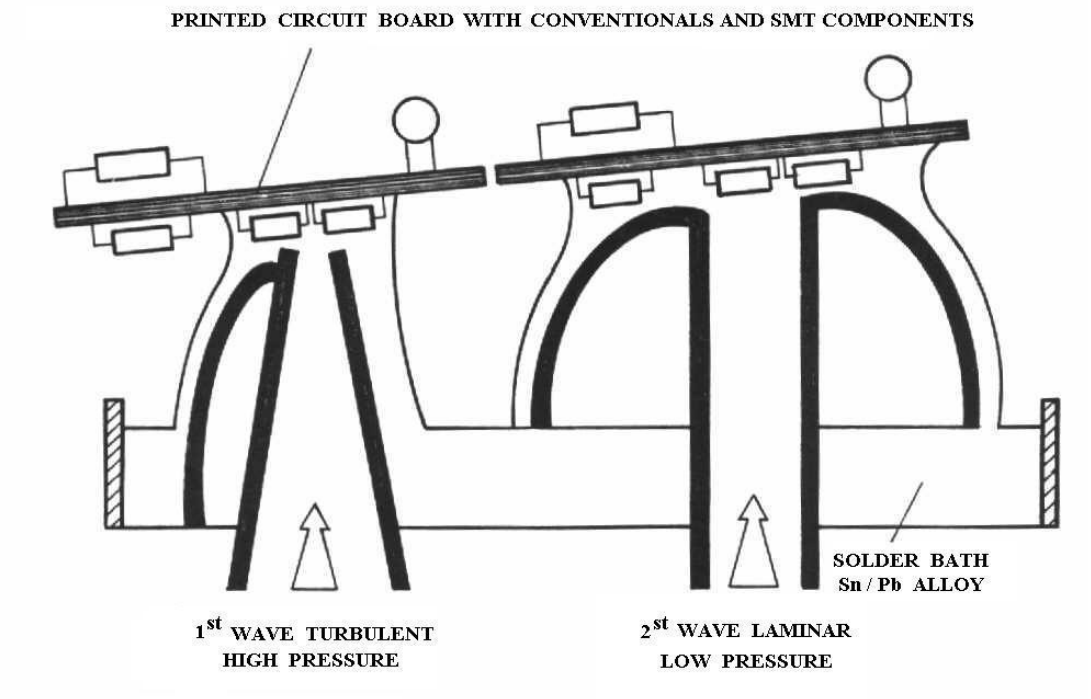

Figure 1. Scheme of the soldering machine by double wave. (VELARDEZ; GRIGOLETTO, 1990).

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Soldering process by reflow

The soldering process of SMC components by reflow is carried out using a solder paste, which after being melted is the linking agent between the SMT components and the printed circuit board. The solder paste may be deposited on the printed circuit board by punctual deposition process or by serigraphy. The punctual deposition occurs by means of syringes, which place the paste where the terminals will be soldered. The placing by serigraphy is carried out on a metallic screen covered by rosin like a mask or a stencil, containing the layout of the deposit places of interest. The screen is placed on the printed circuit board and the solder paste is pressed against it with a squeegee. The paste remains in specified places for the soldering of the component terminals. The components are placed on the wet paste either by manual, semi-automatic or automatic processes. The assembled board passes through a heating oven, which possesses temperature zones adequate to the paste outline, to the size of the components and according to the board to be soldered.

Once the soldering process is finished, an examination is carried out where either the components presenting short circuits or placement problems are repaired or, if necessary, the board is rejected.

The soldering process by reflow produces the following residues: solder paste removed from unsatisfactory deposits, solder rests in threads coming from the repair process of solder boards, solder alloys solidified in assembled boards, and emissions of the tin-lead alloy into the air. Figure 2 presents a scheme of a heating oven used in the soldering of electronic components by reflow (VELARDEZ; GRIGOLETTO, 1990).

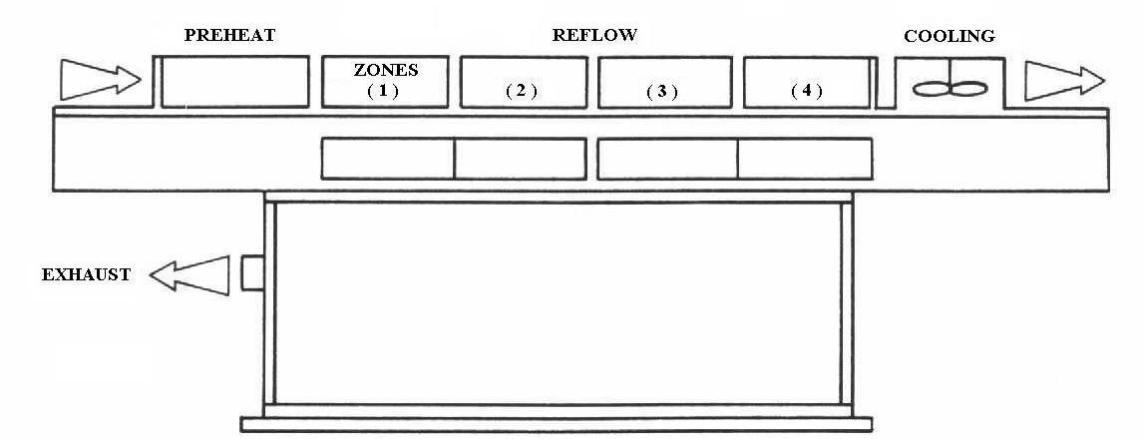

Figure 2. Scheme of a heating oven (Velardez and Grigoletto, 1990).

Lead emission in the manufacture of solder alloys and pastes

According to studies carried out by the Environmental Protection Agency (EPA), the organization responsible for environmental conservation in the USA, the manufacture industry of solder alloys is not a very important source of lead emission.

Research has identified two areas in the manufacture of solder alloys as potential sources of lead emission, which are lead melting and solder paste production. The lead emissions from these sources occur by the same lead emission mechanism as that one applied to the production of lead acid batteries. Nevertheless, the quantity of lead discharged is smaller,

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due to the low lead content of the produced alloy. In the production of solder paste, small lead emission is estimated because the particles in such material present size and density, which give them enough settling velocity to prevent their diffusion into the atmosphere.

Lead emissions tend to present a reduction in the future due to the high demand of solder alloys and pastes, which do not include this element in their composition, such as Sn/Cu, Sn/Sb, Sn/Ag/Cu and Sn/Sb/Ag alloys. Also, effective control devices, such as bag filters and gas scrubbers (EPA, 1998) have increased for the removal of this kind of environmental contaminant as lead is emitted as particulate material in solder industry installations.

Conclusions

Lead is a used metal in industry and is present in the environment as a contaminant. Considering the refinement of mineral lead to obtain the finished product, this metal is a source of particulate materials. This metal always remains in the environment, as particulate material in the air, or as metallic lead in the soil and water.

Heavy metals are generally highly toxic. Particularly for lead, it is important to ban it of the products, because this element competes with calcium in the organism of animals, the consequences of poisoning are serious. Intoxication caused by long-term exposition to low quantities of the metal is restricted to the industrial activities, which manipulate lead. The fact that this intoxication occurs in the working environment is exactly why lead control is extremely important, in order to protect the employees.

SMC component soldering processes on printed circuit boards generate various residues, such as the solder paste that remains from wrong placing, or the solid solder alloy in printed circuit boards, which could not be recovered.

The RoHS and WEEE European Directives helped the electro-electronic producers to achieve solutions to decrease environmental pollution due to the toxic elements traditionally used in the electro-electronic industry. The Directives are influencing the market and the recovery of electronic equipment as the recycling of different materials are been a reality.

Brazilian electro-electronic industries that export to Europe are RoHS compliant. It should be interesting if there were financial incentives to recycling scraps and obsolets products.

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