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Case of introduction of new ecologically safe material

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Materials

ABSTRACT

Purpose: In European Union countries by January 1st 2007 at the latest, all articles and products containing cadmium will either have to be withdrawn from sale or an appropriate substitute for this heavy metal will have to be found.
Design/methodology/approach: The present technology of production of fuses in Slovenian firm ETI Elektroelement and the action thereof are adapted to the existing ecologically harmful alloy of tin and cadmium SnCd20, which ought to be replaced by one or more ecologically safe alloys with technological and application properties as similar as possible to the existing ones.
Findings: In the frame of our common investigation work we have found that the stated problems can be successfully solved by the low melting alloy of tin, bismuth and antimony named ETI-Sn-Bi-Sb.
Research limitations/implications: Alloy is ecologically safe, and by its technical and physical properties corresponds to the requirements of the use for fusible elements of low voltage fuses.
Practical implications: Practical implications of this work is in introduction of new ecologically safe material for fusible elements, without cadmium in the existing technology of low voltage fuses.
Originality/value: Originality and high value of our engineering work is confirmed by two Slovenian national patents and European Union patent for the ecologically safe low melting alloy ETI-Sn-Bi-Sb, which received Slovenian firm ETI Elektroelement and authors of this paper.
Keywords: Metallic alloys; Ecologically safe material; Fusible element

1. Introduction

Every manufactured product has ecological impacts during its life-cycle. These arise in products manufacture, use, recycling and disposal. In the past engineers have focussed only on technical and economical aspects when developing new materials and products, taking into account market conditions and their company's resources. However, developing a new materials and products in accordance with ecological demands requires that engineers consider potential influences from all parts of products life cycle. Developing of ecologically safe materials and products gains an increasing importance in science and industry [1].

In European Union countries the legalisation forbids the production, processing and use of cadmium. By January 1st 2007 at the latest, all articles containing cadmium will either have to be withdrawn from sale or an appropriate substitute for this heavy metal will have to be found. That was the main reason that Slovenian firm ETI Elektroelement still in year 2002 started intensive investigation cooperation with the two members of University of Ljubljana: Faculty of Natural Sciences and Engineering, and Faculty of Mechanical Engineering.

The present technology of production of fuses in ETI Elektroelement and the action thereof are adapted to the existing ecologically harmful alloy of tin and cadmium SnCd20, which ought to be replaced by one or more ecologically safe alloys with technological and application properties as similar as possible to the existing ones [2].

2. Technical problem

Low melting alloys are functional components of low voltage high capacity blade-contact fuses (Figure 1).

Fig 1. Low voltage high capacity blade-contact fuse

When an increased current runs through the fuse, the fusible element representing a vital part of the fuse heats up. If the temperature exceeds the melting point of the low melting alloy, the latter melts and begins to melt the fusible element, which is normally made of copper, silver or new silver, at an exactly defined position [3]. The higher is the temperature the faster is melting, which is stopped by the breaking of the fusible element and an interruption of the circuit (Figure 2).

When selecting the low melting alloys there should be considered their electrical, technological and ecological properties as well as economy [4]. By taking all of them into account, the possibilities if choosing the alloy are relatively limited [5,6,7]. It has turned out that the most suitable are tin-base alloys with chosen appropriate major alloying elements and a possible addition of minor alloying elements for the correction and optimization of the properties of the alloy.

As major alloying elements only bismuth and indium are technologically and economically acceptable. The properties of the alloys comprising these alloying elements are in principle and actually very different from the ones comprising cadmium. Therefore there must be provided additional alloying elements making the essential technological and application properties of the new alloys as similar as possible to SnCd20.

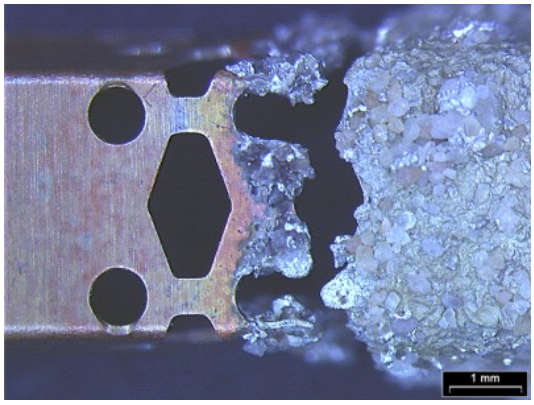

Fig 2. Fuse element broken to the interruption of the current by the melting phase. The right part of the fuse element is coated with low melting alloy [3]

Thus, there existed a need for a new alloy, which would be environmentally acceptable in its composition and, with regard to its technical and technological as well as physical properties, could replace the existing ecologically harmful alloys for fusible elements of low voltage fuses.

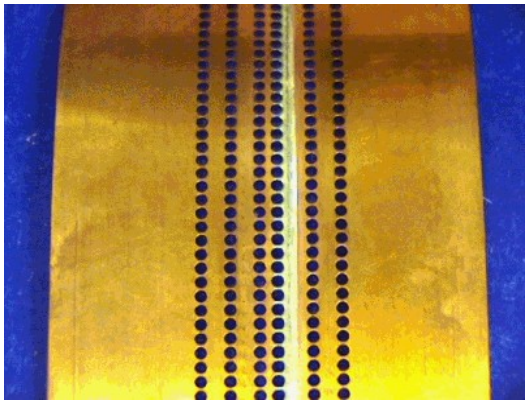

Fig 3. Band made of technical pure copper and at an exactly defined position a layer of a solder made of a low melt alloy and a few millimeters wide .

On each fusible element normally made of technical pure copper of very narrow tolerances (up to ± 0.003 mm) and with a conductivity of 58.8×10^6 S/m, there is applied, at an exactly defined position, a layer of a solder made of a tin-cadmium alloy and a few millimeters wide (Figure 3). This alloy is very important for a correct action of the fuse since by a correct proportion of the two elements it is achieved that at a defined overload current the fuse interrupts the circuit within the prescribed time and thus protects the installation and the user (transformer, engine,…) from being destroyed.

It is known that cadmium is an element, which, already in small amounts, is very toxic to natural substances and living beings [8]. In European Union countries the legalisation forbids the production, processing and use of cadmium. By January 1st 2007 at the latest, all articles (colours, batteries) containing

cadmium will either have to be withdrawn from sale or an appropriate substitute for this heavy metal will have to be found [9].

There are also known alloys of lead and tin (Pb-Sn), which are also harmful to the environment due to the toxicity of lead. Alloys that do not contain ecologically harmful elements like Cd and Pb, e.g. combinations Zn-Ag-Bi-Cu and Zn-In-Al, are used as well, yet due to their technical and physical properties such as melting point, wettability etc., they are limited only to certain uses. In reference [3] there are described solders from tin - base alloys in combination with bismuth, copper and indium, which, however, are economically doubtful due to the high price of indium.

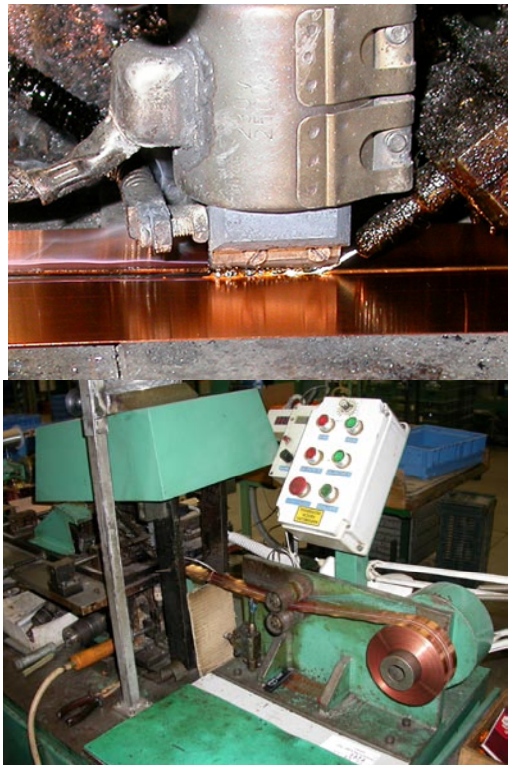

Fig 4. Production technology

The present technology of production [10] of fuses (Figure 4) and the action thereof are adapted to the existing environmentally harmful alloy of tin and cadmium SnCd20, which ought to be replaced by one or more ecologically safe alloys with technological and application properties as similar as possible to the existing ones.

3. Technical solution

We have found that the stated problems can be successfully solved by the low melting alloy of tin, bismuth and antimony ETI-Sn-Bi-Sb [11,12,13], which is ecologically safe and by its technical and physical properties (melting point, conductivity, wettability) corresponds to the requirements of the use for fusible elements of low voltage fuses.

The low melting alloy ETI-Sn-Bi-Sb containing from 4.0 % to 17.0 % by weight of bismuth and from 1.0 % to 3.0 % by weight of antimony, the rest being tin. The above disclosed low melting alloy is produced in the form of definite or infinite wire [14] of a round or square longitudinal cross-section of dimensions (diameter or side length) from 0.5 mm to 3.0 mm.

The ecologically safe low melting alloy of tin, bismuth and antimony ETI-Sn-Bi-Sb by its technical and technological as well as physical properties entirely replaces the existing harmful alloys of tin and cadmium SnCd20 for fusible elements of low voltage fuses.

The most important testing parameter of low voltage fuses is I-t (electric current – breaking time) characteristics. In the frame of our investigation work a complex analysis of a different compositions and dimensions of low melting ETI-Sn-Bi-Sb alloys wires has been carried out. We were testing at two standard testing electric currents for low voltage fuses; at 56 and 70 A. The best (the most similar to the results with the ecologically harmful SnCd20 alloy) results we got with wires of round longitudinal cross-section with the diameter of 1.0 mm and following chemical composition: 10.0 % by weight of bismuth and 1.5 % by weight of antimony, the rest being tin (Figures 5,6), alloy SnBi10Sb1.5.

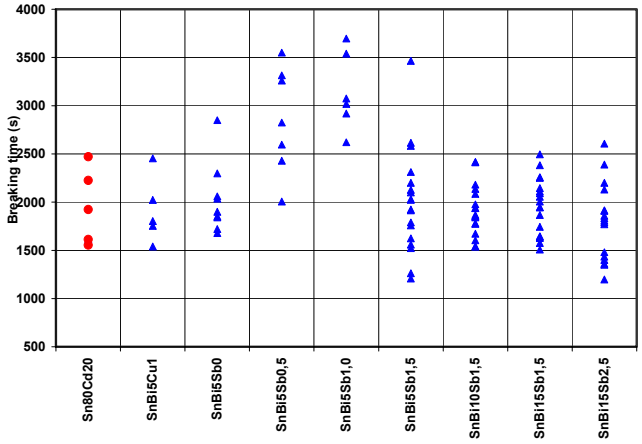

Fig. 5. Breaking time at electric current I = 56 A

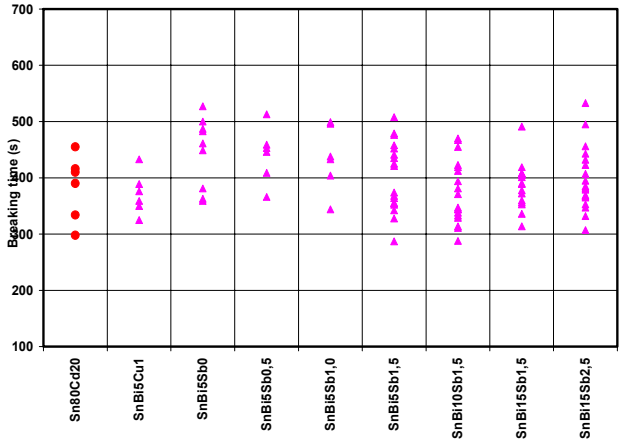

Fig. 6. Breaking time at electric current I = 70 A

4. Conclusions

We have found that the stated problems can be successfully solved by the low melting alloy of tin, bismuth and antimony named ETI-Sn-Bi-Sb, which is ecologically safe and by its technical and physical properties (melting point, conductivity, wettability) corresponds to the requirements of the use for fusible elements of low voltage fuses.

Alloy ETI-Sn-Bi-Sb by its technical and technological as well as physical and electrical properties entirely replaces the existing harmful alloy of tin and cadmium SnCd20 for fusible elements of low voltage fuses

ETI Elektroelement and authors of this paper received two Slovenian national patents, and European Union patent for the ecologically safe low melting alloy ETI-Sn-Bi-Sb.

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