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CASE REPORT

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Analysis of a Soldered Wire Burnt in a Fire

ABSTRACT: Fire investigators frequently encounter electrical wires with melted ends at fire scenes, which can provide useful information on the cause and development of the fire even when the melted ends result from the fires. A bead on a melted end of a wire was found in the area of origin of a massive fire that lasted for nearly a whole day, devastating a factory. The bead appeared to be the end of a wire soldered to a terminal. X-ray analysis showed that the bead is a tin–copper alloy. Although regular tin–lead solder was used in the factory, lead was not detected. This contradictory result stood in the way of fire investigation. Therefore, an unused wire soldered with tin–lead solder was heated in an electric furnace at 500°C for 3 h for further examination. X-ray analysis of this wire showed that copper can be alloyed with tin while losing lead in a long-term heat in a fire.

KEYWORDS: forensic science, fire investigation, arc bead, soldered wire, alloying, copper, tin, lead

Electrical distribution wires with melted ends showing beaded, drop-shaped, and pointed shapes are frequently encountered after fires. These melted wires can provide fire investigators and forensic scientists with useful information on the progress of a fire even when they are not its cause (1–4). If a bead is found at the point of origin, it should be examined carefully because of its possible relevance to the cause of the fire. Even if the bead was produced by an arcing short resulting from the thermal breakdown of its insulating material in a fire, it can be used to deduce how the fire spread. If the bead was melted by exposure to the heat of a fire, it can provide information on the area where the temperature was high enough to melt the wires.

The Fire Scene

A bead of copper alloy was found in the fire debris of a large factory. The facilities in the factory were severely burnt in the fire, which was finally contained nearly a day after it started. The cause of the fire was suspected to be an electrical failure. Most of the electrical wiring used for the facilities turned brittle and broke into small pieces. Only a few beaded wires were found in the debris in the factory area where the fire originated. One bead had the appearance of an arc bead in terms of its round shape and smooth surface as shown in Fig. 1. X-ray analysis was performed to determine where the bead came from. The methods and results of the analysis are discussed in the following sections.

Materials and Methods

The bead in Fig. 1 and a control sample for comparison were elementally analyzed. The control sample was prepared by heating an unused wire soldered with tin–lead solder at its end in an electric furnace at 500°C for 3 h. The solder used for the control sample had the same of 60% tin and 40% lead composition as the solder used in the factory. The beads in Fig. 1 and the control sample were mounted in resin and polished with emery paper and diamond paste. Subsequently, the images and characteristic x-ray spectra from the beads were recorded with a scanning electron microscope and an energy-dispersive X-ray analyzer (SEM/EDXA) using a 20 kV electron beam.

Results

Copper conductors can form alloyed areas with metals such as aluminum, zinc, silver, and solder in fires (2–4). The cross-section of the bead in Fig. 1 was uniformly silver-colored, indicating that the copper conductor had become alloyed over the entire area of the bead. Figure 2 shows an SEM image of the cross-section of the bead.

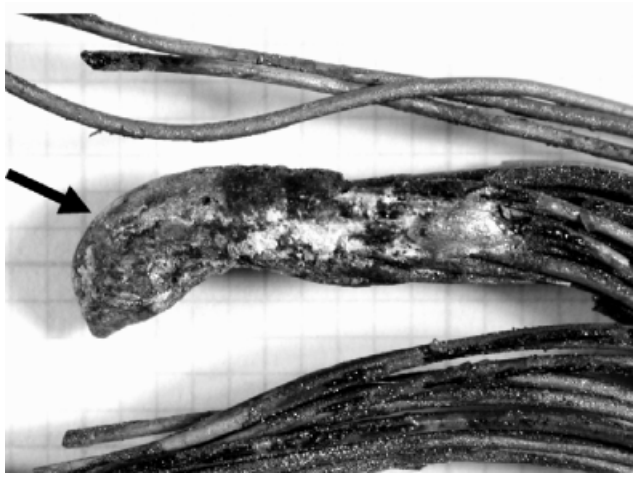

FIG. 1—*A bead found in the fire debris.*

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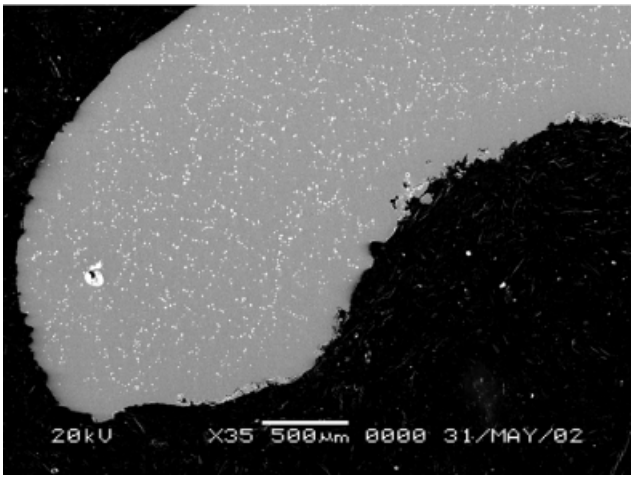

FIG. 2—*SEM image of the cross-section of the bead in Fig. 1.*

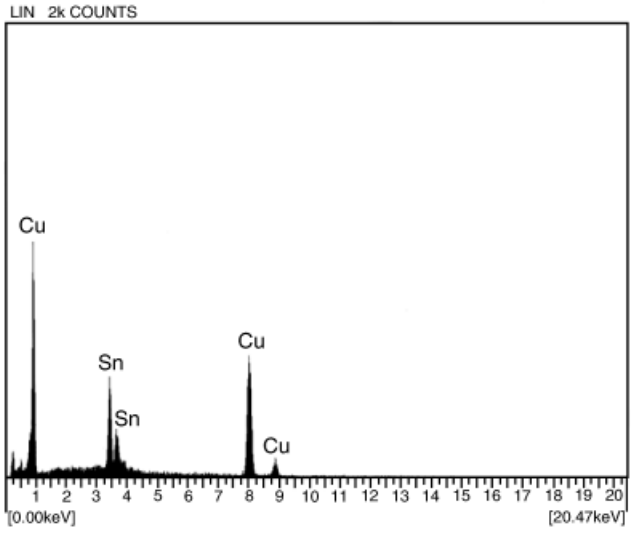

FIG. 3—*X-ray spectrum of the bead in Fig. 1.*

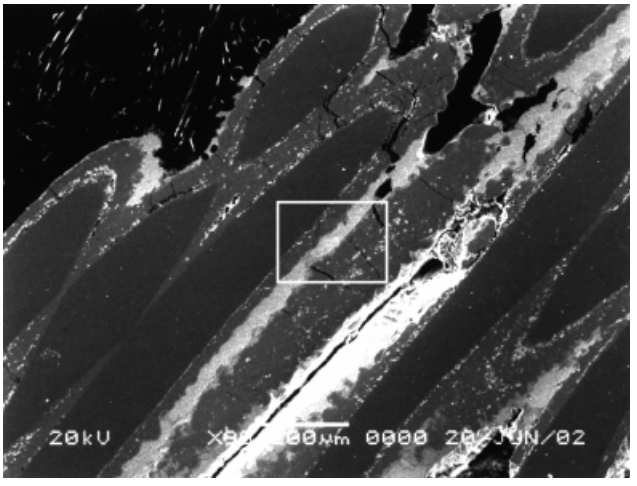

FIG. 4—*SEM image of the control sample.*

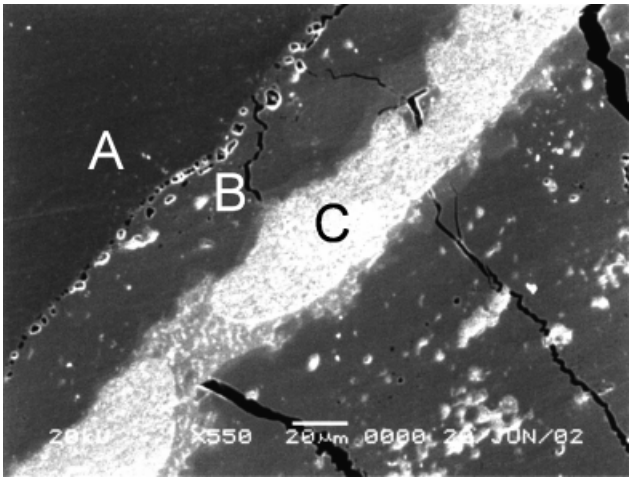

FIG. 5—*SEM image corresponding to the squared area in Fig. 4.*

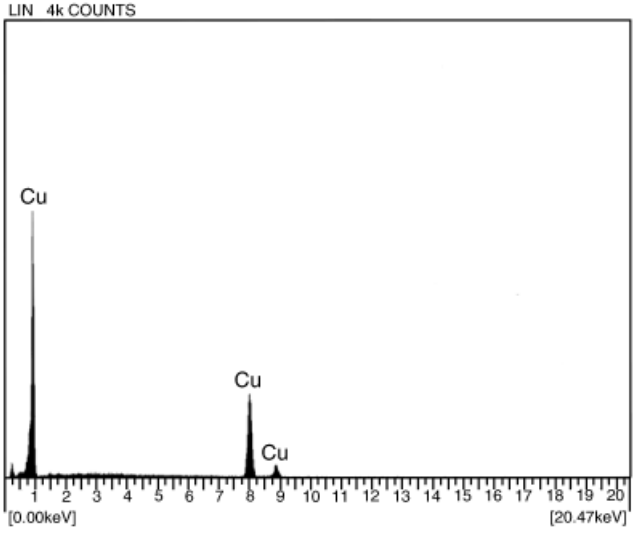

FIG. 6—*X-ray spectrum at region A in Fig. 5.*

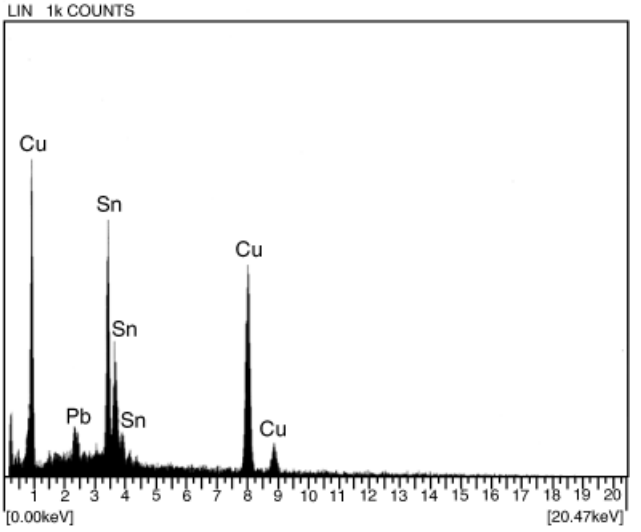

FIG. 7—*X-ray spectrum at region B in Fig. 5.*

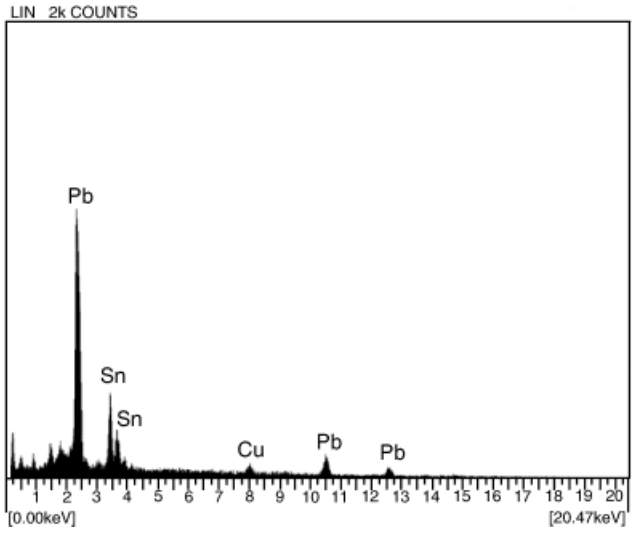

FIG. 8—*X-ray spectrum at region C in Fig. 5.*

The X-ray spectrum in Fig. 3 indicates that the copper conductor bead is alloyed only with tin. Lead was not detected in the bead. This suggests the possibility that a lead-free solder might have been used for the connection, while only lead–tin solder was actually used in the factory.

Figures 4 and 5 show SEM images of the control sample. The spectra in Figs. 6–8 indicate that regions A, B, and C in Fig. 5 are composed of copper, tin–copper, and tin–lead, respectively. B is a tin–copper alloy that was newly formed between the copper conductor and tin–lead solder.

Discussion

The analysis results indicate that the lead-free region B in Fig. 5 corresponds to the entire cross-section of the bead in Fig. 2. However, the question remains as to why lead is missing from the bead in the factory fire.

This can be explained by observing that lead remains only at region C in Fig. 5. Note that the white-colored regions in Fig. 4, which correspond to region C, are observed mainly between the inner strands of the wire. That is, more lead vaporizes from the outer strands during the furnace heat treatment than from the inner strands. If the control sample is heated for a longer time, the entire region will convert to tin–copper alloy.

Conclusion

Although elemental analysis of beads on electrical wires plays a potentially important role in investigating fire scenes, it does not always provide fire investigators and forensic scientists with straightforward information. The factory fire in this report is one such example. X-ray analysis of a bead at the end of a soldered wire found in the fire debris revealed that the copper conductor of wire had become alloyed only with tin and that lead was lost during long-term heating in the fire. If the bead had been interpreted differently, it might have misled the fire investigation. Such evidence must be carefully examined to avoid such pitfalls.

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