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THE TECHNOLOGY OF FORENSIC EXAMINATION OF BURNED COPPER CORD

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Abstract: Technical forensics is a very broad scientific field. This paper reports one of its aspects, which refer to the testing of electrical conductors following a fire in order to identify the real cause of its appearance, namely providing information whether or not the electric cord damage caused the fire and to offer contribution to the authorities. For this purpose, sectional tests of copper electric cord were conducted using microstructure optical microscope as well as X-ray diffraction analysis. The sample preparation process has been also described. The interpretation of the obtained results with the adopted conclusions based on the above-mentioned tests was presented. Based on these analyses, it was concluded that there was a local melting of the conductors influenced by high temperatures achieved in oxygen atmosphere, and that melting was apparent within all samples.

Keywords: forensics, optical microscopy, X-ray diffraction analysis.

1. Introduction

Technical forensics as a multidisciplinary science is directly related to the technological development and therefore requires continuous training and research, as well as brand new equipment. It is difficult to discover and prove crimes, particularly in the terms of evidence (Maksimović et al., 1998). The main objective is to obtain as accurate results as possible on the basis of which it is possible to draw more certain conclusions. The

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main objective of each analysis is risk mitigation, and depending on the parameters that characterize it, there is a wide choice of available methodologies (Mašković, 2009).

Rapid technological and scientific development leads to new physicochemical and chemical methods, which have become very efficient in the process of detecting and solving various criminal events (Maksimović et al., 1998; Mašković et al., 2009). Modern technical forensics has allowed the elimination of such doubts. Results obtained by forensic tests are often the only evidence regarding the aforementioned events. These results often determine the nature of the event uniquely, so there is no room for any attempt of manipulation, which simplifies further proceeding steps of the Ministry in charged. In addition to the basic methods used in modern crime laboratories (Cox et al., 2000; Cengiz et al., 2004; Kruesemann, 2009; Lendev & Virkler, 2009), commonly used techniques are microstructural analysis using optical microscopy, X-ray diffraction and X-ray analysis (Rendle, 2003; Ruffell & Wiltshire, 2004). The data obtained, with the help of forensic procedures, can assist in gathering the necessary information to solve the task. The choice of methods for identification itself and detailed characterization of this material is very important, along with necessary evidence revealed and mandatory testing in practice (Maksimović et al., 1998).

The aim of this paper is to bring technology of electrical conductors and in regard to this to reveal if the fire at the time of installation was under voltage, or whether it was a short circuit that caused the fire. A fire caused by a short circuit in the electrical installation is one of the most frequently cited reason for that kind of accidents, beyond which often human carelessness, envy, greed and so on was hidden.

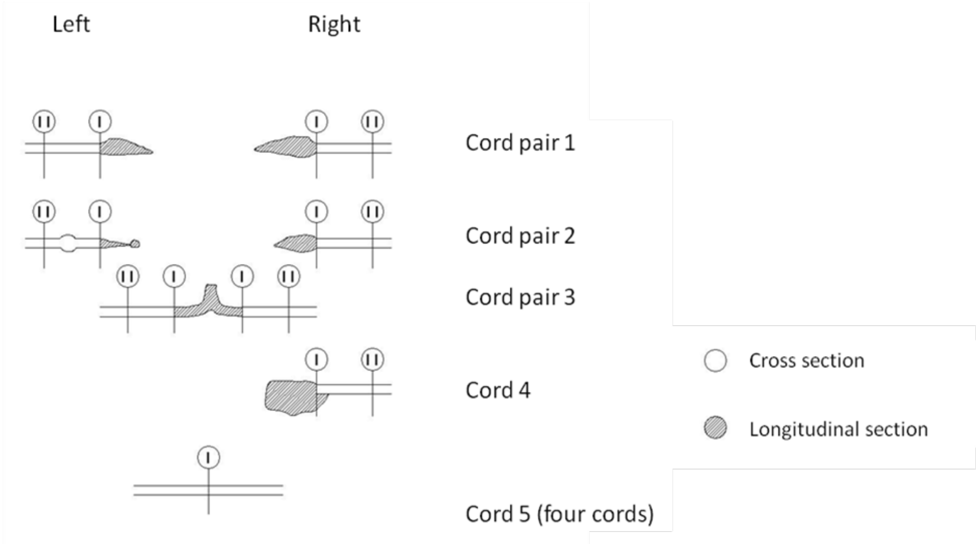
2. Experimental Sample Analysis

The obtained samples for the analysis were copper cords of the mean diameter of 1.4 mm and in length of about 23 cm. Prior to performing the microstructural analysis, the visual inspection of cords were carried out, and it was observed that all the samples were heavily oxidized.

Prior to any experiment, it is necessary to prepare the sample, which is just as important as the test itself. The sample preparation for metallographic examination begins with sampling itself. It is necessary to form and customize the size of the investigated sample to the conditions of the next phase. Applying the diamond saw (chosen as small as possible cutting width, optimally about 0.3 mm) one cuts off the sample, with mandatory water cooling in order to avoid structure deformation along the cut. Two cross-sections along the conductor were made, approximately at 25 mm and 35 mm of the fused cord tops. Sharp edges need to be rounded in order to avoid damage of the polishing grit. Longitudinal sections were made from fused cord tops by grinding using SiC papers. In addition, Al_2O_3 with 15-30% of Fe_2O_3 and Al_2O_3 can be used with mandatory cooling in order to avoid possible change in the structure if the sample was heated.

The obtained samples are dipped in two-component cold-hardening acrylate and are prepared by grinding with SiC papers of 100-240 fineness (0.149 to 0.062 mm grain size). The process begins using the roughest paper while the pattern runs in the same plain axis and in both directions while on the surface does not remain grinded only in that direction. Then the sample is carefully cleaned and the process is repeated with a finer paper in the direction perpendicular to the previous one, until the scratches of previous drilling are lost. The process is repeated using finer papers (Đorđević & Vukićević, 1994). Mechanical preparation is completed by polishing which removes sanding scratches and until the gloss surface is achieved (Đorđević & Vukićević, 1994). Polishing is made with discs coated in fabrics with the mandatory use of alumina (Al_2O_3 and MgO) or diamond paste.

After mechanical preparation, electrolytic etching of surfaces is applied, in order to expose the structure. Polished metallographic sample is immersed in a solution of HNO_3 in methyl alcohol in the ratio of 1:2 at a voltage of 20V and current of 150 mA for 20 s after which the sample is rinsed with distilled water and alcohol, and then dried with paper and in hot air.

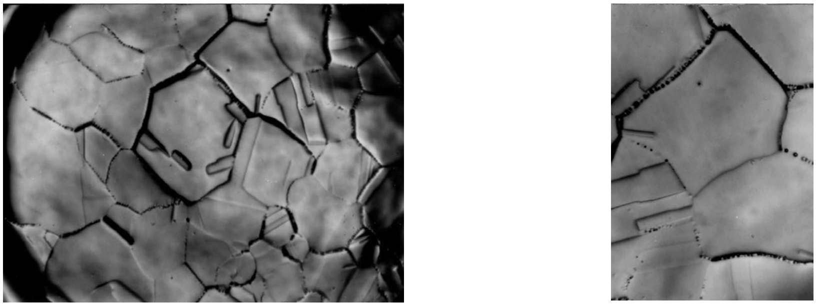


Scheme of the analyzed samples

3. Results and Discussion

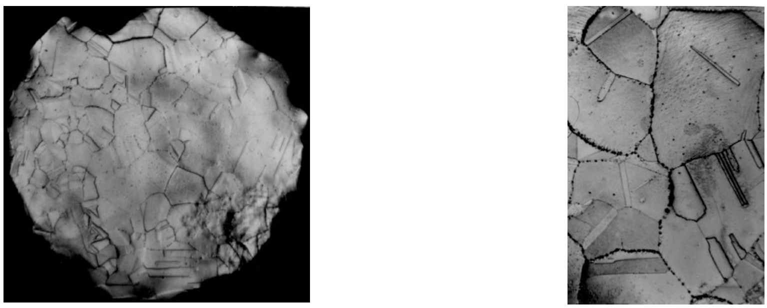
3.1 Results Obtained by Optical Microscopy

Figures 1 show an overview of the microstructure of the first pair of cords. If the attention to the cord cross-sections which make pairs was paid, it was noted that large and polygonal grains appear. It is also evident in grains, twins that are characteristic of the annealed structure. At the grain boundaries, some globular inclusions were pronounced. On longitudinal sections the dendrite structure is apparent, i.e. the structure formed by melting and solidification of metallic conductors. The dark microconstituent that was isolated during the curing process exists in the interdendritic space. The figure also denotes the sharp line between the structures, appeared as a result of melting and solidification of grain that were under the influence of high temperature.



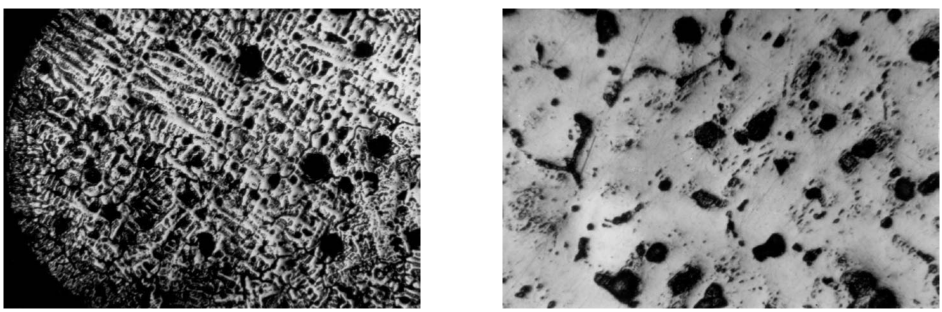
a) b)

Figure 1.1: *The microstructure of the first cross section of the left part of cord 1 with a magnification of a) 112 b) 224*



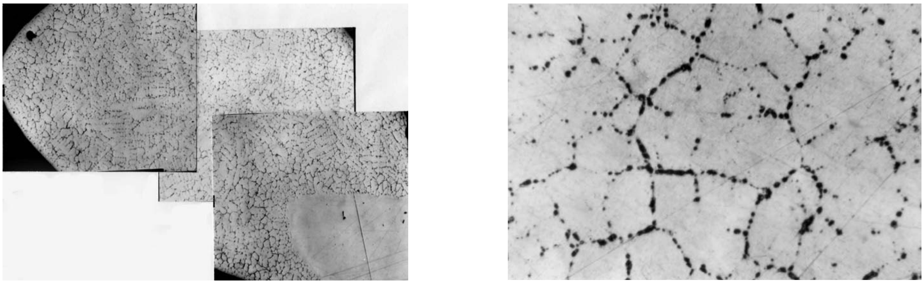
a) b)

Figure 1.2: *The microstructure of the second cross section of the left part of cord 1 with a magnification of a) 84 b) 224*



a) b)

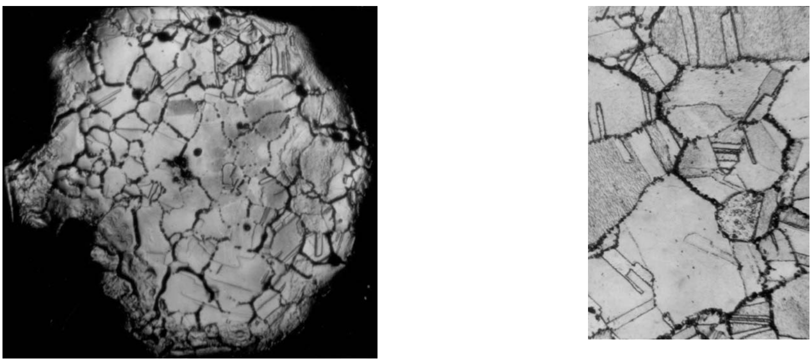
Figure 1.3: *The microstructure of the longitudinal section of the left part of the cord 1 with a magnification of a) 56 b) 224*



a) b)

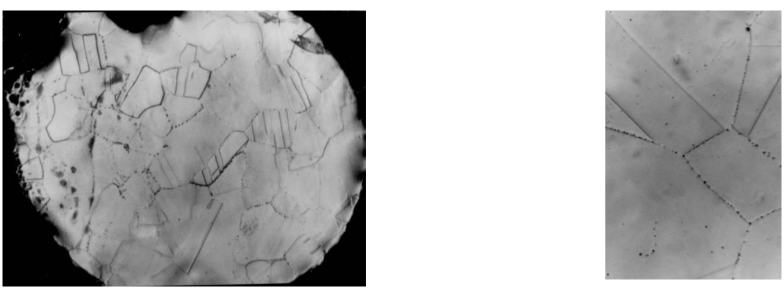
Figure 1.4: *The microstructure of the longitudinal section of the right part of the cord 1 with a magnification of a) 56 b) 224*

The microstructure of the second pair of cords is not significantly different from the first pair of cords, which was confirmed in Figures 2.1 and 2.2, which show the grains after the effect of high temperature and the dendrite structure formed by melting and solidification. However, Figure 2.3 shows the reduction in the section behind the hardened metal droplets, regarding the termination of conductors after the separation of the drop.



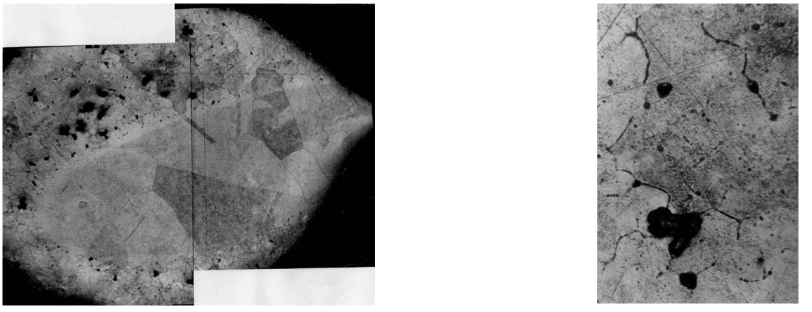
a) b)

Figure 2.1: *The microstructure of the cross section of the left part of cord 2 with a magnification of a) 84 b) 224*



a) b)

Figure 2.2: *The microstructure of the cross section of the right part of cord 2 with a magnification of a) 84 b) 224*



a) b)

Figure 2.3: *Microstructure of droplet separated from the top left part of cord 2 with a magnification of a) 56 b) 224*

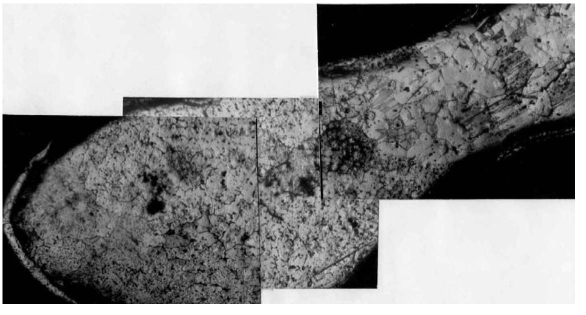
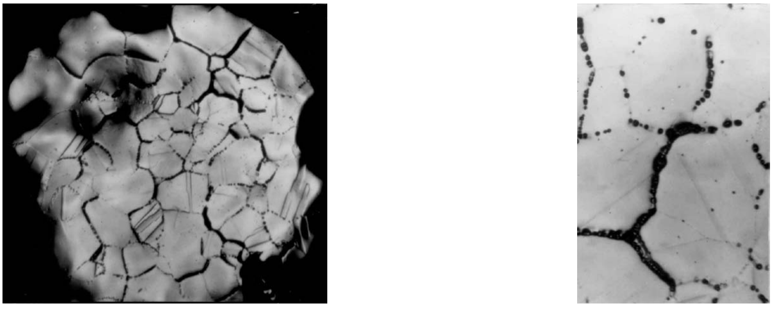


Figure 2.4: *The microstructure of the longitudinal section of the right part of cord 2 with a magnification of 56*

Cross section of twisted pair cord 3 (Figure 3) shows large polygonal grains with inclusions. On longitudinal section it can be seen that there has been a merging of the two conductors as well as that the structure is dendritic. There is a noticeable difference in the size of dendritic branches as well as in the quantity of interdendritic microconstituents within the width of longitudinal section.



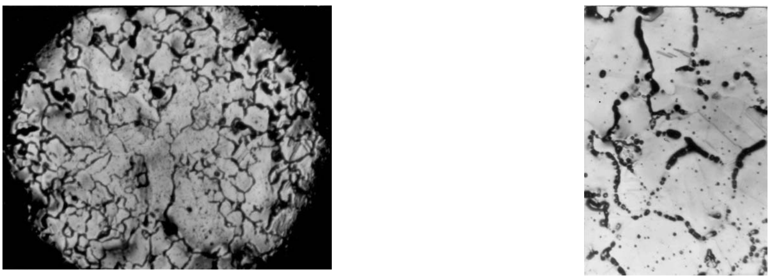
a) b)

Figure 3.1: *The microstructure of the first cross section of cord 3 with magnification of a) 84 b) 336*

a) b)

Figure 3.2: *The microstructure of the longitudinal section of cord 3 with magnification of a) 56 b) 224*

On cross section of cord 4, grains are irregular and roughed. Globular inclusions in the structure are visible at the edges of cord 4, which is different from the others. It is a structure formed by annealing cast and not deformed structure, as is the case with other cords. This is even more evident in the second cross section. Longitudinal section shows the cord together with fused material (Figures 4). Dendrites of fused materials, diffusion zones and large polygonal cord grains are observed. Cord grain edges are very bold, which indicates the beginning of the local cord melting. Segregation presence in dendrites of the fused material indicates that this material is solid solution based on copper.



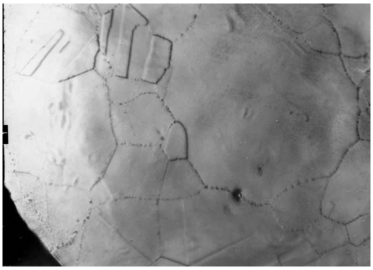
a) b)

Figure 4.1: *The microstructure of the cross section of cord 4 with magnification of a) 56 b) 336*

a) b)

Figure 4.2: *The microstructure of the longitudinal section of cord 4 with magnification of a) 56 b) 336*

The microstructure of the sample cut out from one of the cords (all 4 cords show the same structure) is shown in Figure 5. Polygonal grains with double annealing and single inclusions at grain edges are observed.

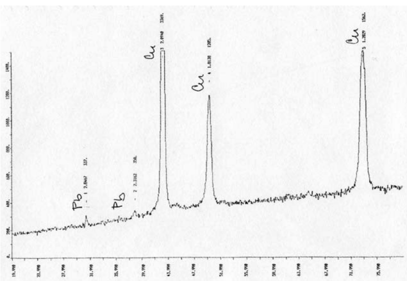


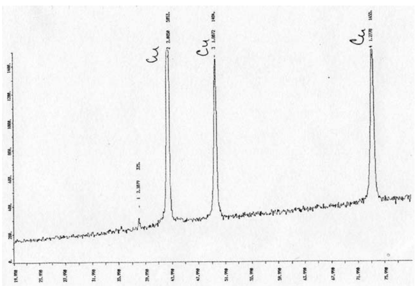
a) b)

Figure 5: *The microstructure of the cross section of cord 5 with a magnificationof a) 112 b) 224*

3.2 Results Obtained By X-Ray Analysis

Figure 6 shows the radiographs of examined cords. Depending on the cords, except a reflection of Cu, reflections of Cu_2O, Pb and solid solution based on Cu were detected. Pb is present in the cords labeled 1 and 4 while Cu_2O was detected in cords 3 and 4. As the reflections (peaks) for Cu_2O and Pb are matching, perhaps a reflection of Cu_2O is present in the sample cord 1, especially as this phase is observed in micrograph of this sample cord. Solid solution based on Cu is present in the sample fourth cord.





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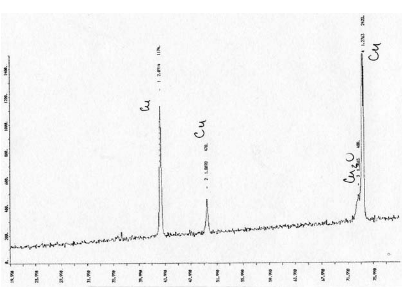

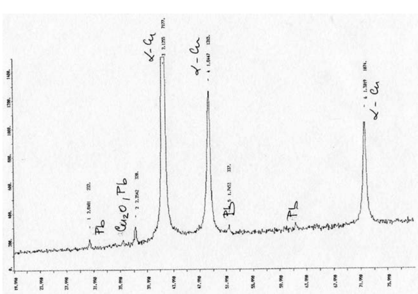

c) d)

Figure 6: *Radiographs of a) cord 1, b) cord 2, c) cord 3 and d) cord4*

The microstructure of the cord possesses two different structures, the structure formed by melting and solidification and the structure emerged upon high-temperature annealing. At the cord tips, a dendrite structure appears, i.e. structure that was formed by melting and solidification of the copper cord. Microconstituents that is present in the interdendritic gap is dual eutectic of Cu-Cu_2O type. In order to reach the conductor melting, the temperature had to exceed 1083 °C (Đorđević, 2000), and to form a Cu-Cu_2O eutectic, the atmosphere around the conductor had to be rich in oxygen so it could diffuse in the liquid metal. The absence of oxygen, i.e. Cu_2O in grains between melted material and grains themselves, can be explained by the large difference in the solubility of oxygen in liquid and solid copper (Hansen, 1958). This probably indicates that the oxygen, except from the atmosphere, also diffused from a solid to a liquid metal during solidification.

Large polygonal grains are approximately two orders of magnitude larger than the grains in the commercial cord of the same cross section. The grains are not uniform in size and annealing twins are present which indicates that these grains grown under the influence of temperature. The presence of globular inclusions of Cu_2O along the grain edges indicate the diffusion of oxygen upon heating as well as that the temperature of conductor was above 375 °C (Hansen, 1958), the temperature above which the Cu_2O is stable, and probably even above 600 °C, above which the oxygen shows significant diffusion coefficient (Smithells, 1967) in solid copper.

The microstructure of the labeled 4 conductor has grains that are formed by melting, solidification and high-temperature annealing of dendrites in the presence of oxygen. This indicates that this cord was heated to a higher temperature than the other tested cords. The presence of Pb in the radiograms of the cord 1, and especially of the cord 4, indicates the type of material fused to the cord labeled 4, which is probably fused hard brass with a lead content up to 2 % (Schumann, 1981). The fact that Zn vapors at temperatures above 907 °C (especially above 1000 °C) and that its vapors immediately react with oxygen forming ZnO and that the conductor temperature exceeded 1083 °C at spots of local melting, suggests that most of the Zn evaporated, thus explaining its absence as well as the presence of a solid solution based on Cu and Pb on radiographs. The presence of Pb is explained by its vaporization temperature of 1750 °C (Davis, 2001), which also shows that the temperature has not reached that value.

4. Conclusion

The local melting of the conductors when high temperatures were applied was apparent. The presence of Cu-Cu_2O eutectic in the conductor structure indicated that the melting occurred in an atmosphere that contained oxygen. Melting was observed in all 4 cord pairs. All tested conductors had coarse grain structure of Cu_2O inclusions at grain edges, indicating that the conductors were at a temperature higher than 375 °C and in an atmosphere that contained oxygen. Conductor 4 was exposed to the temperatures higher than the other three conductors. The material that was found fused to the conductor 1 and conductor 4 was probably a hard brass according to the lead residues.

From the above, it was concluded that there was no fire at the time of conducters melting, since the atmosphere was rich in oxygen, which was able to bind to molten copper. Otherwise the oxygen would be consumed during combustion which would prevent the formation of Cu_2O. This confirms that the melting of the conductors was due to a short circuit, i.e. that the installation was under voltage at the time of the fire.

5. References

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TEHNOLOGIJA FORENZIČKOG ISPITIVANJA BAKARNE ŽICE NAKON POŽARA

Rezime

Tehnička forenzika je jako široka naučna oblast. U ovom radu će se govoriti o jednom njenom segmentu koji se odnosi na ispitivanje električnih provodnika nakon požara, u cilju otkrivanja njegovog stvarnog uzroka, tj. prihvatanja ili odbacivanja kvara na elektoinstalacijama kao uzroka požara i pribavljanja informacija istražnim organima za rašavanje postavljenog zadatka. U tu svrhu su izvršena mikrostrukturna ispitivanja preseka bakarne žice korišćenjem optičkog mikroskopa i rendgenostrukturna analiza istih. Opisan je, takođe, i proces pripreme uzoraka kao i tumačenje dobijenih rezultata sa zaključcima donesenim na osnovu pomenutih rezultata ispitivanja. Na osnovu urađenih analiza je zaključeno da je došlo do lokalnog topljenja provodnika pod dejstvom visoke temperature u atmosferi kiseonika, a topljenje je uočeno kod svih ispitivanih uzoraka.