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Development of Mev-Eds Methodology for Forensic Analysis on Automotive Headlights

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Abstract. A comparative study between three automotive headlights (conventional, halogen, and HID lamp) using scanning electron microscopy coupled with energy dispersive spectrometry (SEM-EDS) is described. Results show the possibility of conducting topographic and qualitative analysis of automotive light bulbs from vehicles involved in traffic accidents on the basis of similarities between the waste glass material left on the filaments. This should provide evidence as to whether the bulbs were energized at the time of the accident.
Keywords: Traffic accident; Forensic chemistry; Criminalistics; Scanning electron microscopy.

Resumo. Um estudo comparativo entre três tipos de lâmpadas automotivas (convencional, halógena e lâmpada de xenônio HID) utilizando as técnicas microscopia de varredura linear acoplada ao espectrômetro de energia dispersiva (SEM-EDS) é apresentado. Os resultados apontam a possibilidade de realizar análise topográfica e qualitativa de lâmpadas automotivas de veículos envolvidos em acidentes de trânsito, com base nas semelhanças entre os resíduos vítreos deixados nos filamentos. Este método pode apresentar provas para saber se as lâmpadas foram energizadas no momento do acidente.
Palavras-Chave: Acidentes de trânsito; Química forense; Criminalística; Microscópio de escaneamento eletrônico.

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1. Introduction

1.1Traffic Accidents

Motor vehicle transport has been proven to be the most dangerous of all transport modes worldwide, as judged from the high incidence of accidents involving this type of vehicle. Therefore, it is unarguable that policies regarding transport facilities must be adapted on a global scale, so that reduction in the number of accidents can take place through improved road safety measures[1]. It is clear that fatigue, distraction, consumption of illicit drugs and alcohol, and reduced field driver's vision are essential causes of motoring accidents[1,2]. In some cases, traffic accidents involving vehicles as well as casualties resulting from the accident, mainly injuries to pedestrians during nighttime can be clarified through analysis of trace materials originating from the structure of the vehicle itself as well as through examination of the traffic accident site in terms of tyre prints and vehicle debris. In this context, analysis of the light bulbs from vehicle headlights can furnish important information for forensic research[3], since are can find out whether the bulbs were energized prior to the accident.

1.2 Automotive headlights

Due to the development of new products and competition between manufacturers, a variety of light bulbs for automotive vehicles are currently available. Xenon headlights, also known as illumination of high intensity discharge (HID) because of its efficiency, durability, and the aesthetics it provides to the vehicle, characterized by the intense glow produced during its burning, are the most desired by customers. The arc light is created by an electrical discharge in the xenon gas mixture present between two electrodes located in the bulb. Some manufacturers claim that xenon headlights give rise to a light beam that is 70% more intense as compared to conventional bulbs, which is the reason why they have been widely employed in inexpensive vehicles[4]. Vehicles equipped with HID lamps must comply with the standards of traffic laws enforced in the country where they are to be used. These headlights must be fitted with height adjustment, so that the beam can be corrected in the various conditions encountered by the vehicle such as unevenness and overloaded trunk.

Conventional headlights are cheaper and contain a tungsten filament placed inside the glass bulb, which prevents contact between the filament and the atmosphere. Some inert gas is also added to the bulb. As for incandescent light bulbs, nitrogen or argon gas is employed, whereas iodine or bromine gas is utilized for halogen bulbs. The main function of the gas is to increase the strength and efficiency of the material. Once electrified, the filament glows, thereby creating a bright light. Incandescent bulbs used may differ slightly in terms of size, material, and filament winding; i.e., they are designed according to their function[3,4].

1.3 Scanning electron microscopy

In forensic analysis, the most commonly employed method for examination of motor vehicle accidents is based on the comparison of bulb filaments from the vehicle involved in the accident with a bulb exhibiting the same characteristics (standard sample). With the aid of appropriate instrumentation, are can verify what changes the target sample underwent in a collision involving headlight rupture by means of macroscopic and microscopic analysis[3].

In this context, some interesting works on forensic analysis involving automotive headlights have been published in the literature[5,9]. For instance, scanning electron microscopy (SEM) investigation of halogen bulbs from a vehicle that was involved in a car accident (real case)[8] led to the conclusion that one of the headlights of such vehicle was off prior to the impact, thus evidencing irregular circumstances at the time of the accident.

Scanning electron microscopy coupled to an energy dispersive detector (SEM-EDS) has been extensively applied in forensic research. This technique enables characterization of the surface of an object as well as of the morphology of the particles in the sample, thereby furnishing qualitative and quantitative analytical information, about chemical composition and the presence of defects and impurities[10,13].

Despite the importance of analyzing automotive headlights in episodes of traffic accidents, literature works comparing the different types of commercially available automotive bulbs and studies on the types of fracture traces produced in new products are lacking. This study aims to examine traces of filaments from conventional, halogen, and xenon headlights produced during episodes of simulated traffic accidents by means of the SEM-EDS technique.

2. Experimental

2.1 Materials

Experiments simulating an accident with rupture of the structures of vehicle light bulbs were conducted using personal protective equipment (gloves, goggles, and helmets) in a laboratory environment equipped with rubber gasket and exhaust chapel. The bulbs used in the headlights consisted of 21W light bulbs, 55W or 100W halogen lamps, or 35W-HID lamps. The employed models can be seen in Figure 1.

Figure 1. Different models of automotive lamps available in the market (from left to right): 35W Lamp HID xenon bulb, 55W halogen headlight bulb, 100W halogen headlight bulb, 21W conventional bulb.

2.2 Accident simulation

The experiments accomplished herein aimed to simulate a situation of traffic accident where rupture of the headlight with subsequent production of traces of forensic interest occurs. In the case of conventional and halogen bulbs, a situation where the vehicle headlights were on (energized filaments) was simulated, so that rupture of the glass shield produced typical traces in the filament such as fusion of glass fragments on the surface as well as possible abrupt fractures in the filaments. To achieve such a situation, a circuit consisting of a 12V automotive battery, a 10A fuse, a switch, and sockets for connection to the adapted conventional bulbs and halogen lights was mounted. For experiments involving HID lamps, it was necessary to include a specific reactor. After the lamps were electrically driven, a waiting time of

15 seconds of operation was adopted, which was followed by rupture of the headlight structures by busting with a conventional hammer.

2.3 Microscopic analysis

The filaments of conventional and halogen headlights as well as the electrodes from HID lights were collected and fixed in a conductive double-sided tape, followed by attachment to the microscope stand type stub. The SEM micrographs were taken on a Zeiss equipment EVO® 50, and the energy spectra of the elements were recorded using an accessory for microanalysis IXRF Model 500 Digital Processing. Analysis was carried out the analysis by checking the surfaces extensions of the filaments and electrodes via micro-morphological and qualitative analysis of the samples.

3. Results and Discussion

3.1 MEV-EDS analysis

The micrographs obtained for the conventional bulb filament (Figure 2), the 55W and 100W halogen light bulb (Figure 3 and Figure 4, respectively) and the HID lights (Figure 5) revealed that joint traces were produced in the filament and electrodes. When fracture of the vitreous body of the bulbs was obtained in a state of energized headlight, the glass fragments that reached the surface of the energized filaments and electrode underwent fusion and clinged to the surfaces thereof. Analysis of the metal parts of filaments and electrodes dismissed the use of bathing in gold or graphite, since the samples were naturally conductive. Additionally, chemical analysis coupled to X-ray microanalysis indicated the possibility of identifying the nature of the remains deposited on the target metal parts, which consisted of silicon and oxygen; i.e, they had the same composition as glass (SiO_2). In contrast, carrying out this same chemical analysis on specific sections of the metal parts with no trace of fragments deposition evidenced the nature of the metallic constituent of the filaments and leads, such as tungsten. When non-energized the bulbs were ruptured, it was not possible to detect any of the previously described features.

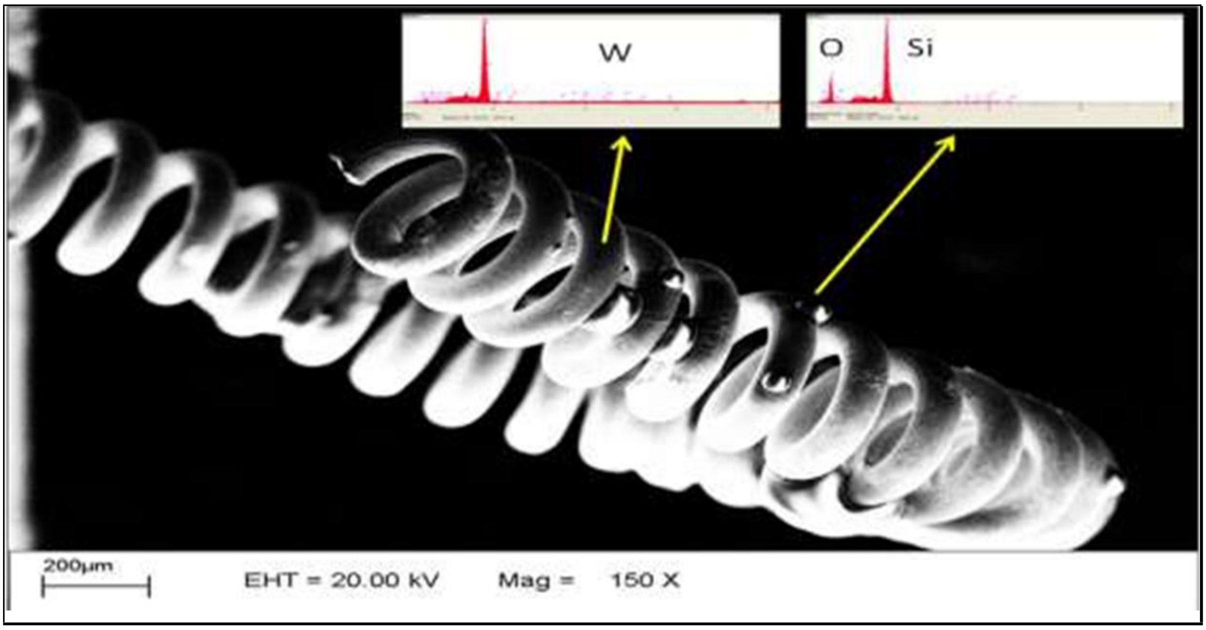

Figure 2. Micrograph of the conventional bulb filament obtained after rupture of the glass structure of the lamp. Chemical analysis by X-ray indicating the nature of the filament surface, which consists of tungsten, as well as the composition of the particulate material cast on the filament, composed of silicon and oxygen.

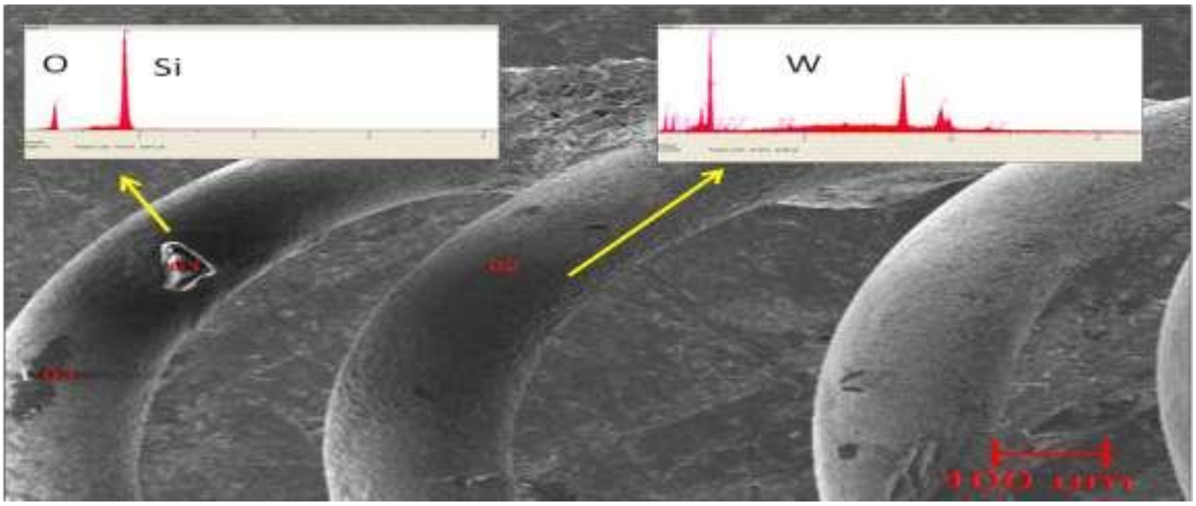

Figure 3. Micrograph of the 55W halogen bulb filament obtained after rupture of the glass structure of the lamp. Chemical analysis by X-ray indicating the nature of the filament surface, which consists of tungsten, as well as the composition of the particulate material cast on the filament, composed of silicon and oxygen.

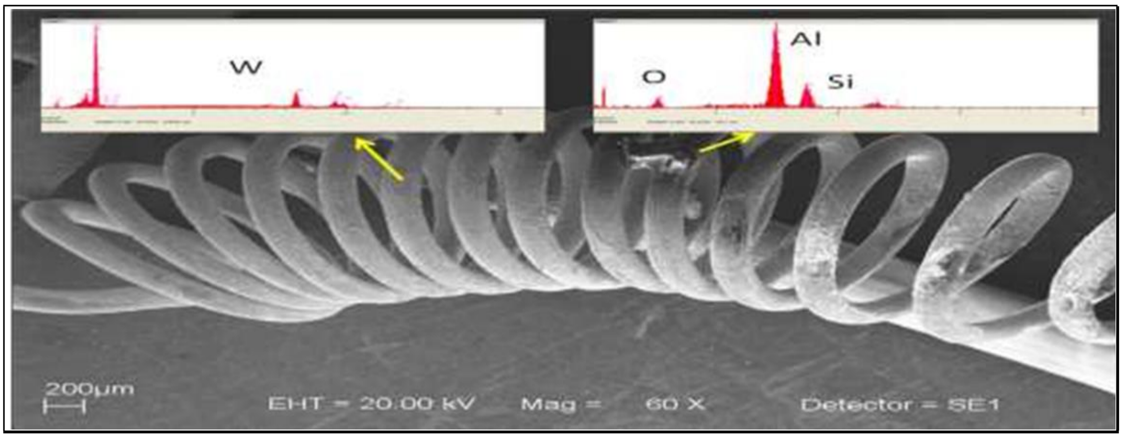

Figure 4. Micrograph of the 100W halogen bulb filament obtained after rupture of the glass structure of the lamp. Chemical analysis by X-ray indicating the nature of the filament surface, which consists of tungsten, as well as the composition of the particulate material cast on the filament, composed of silicon and oxygen.

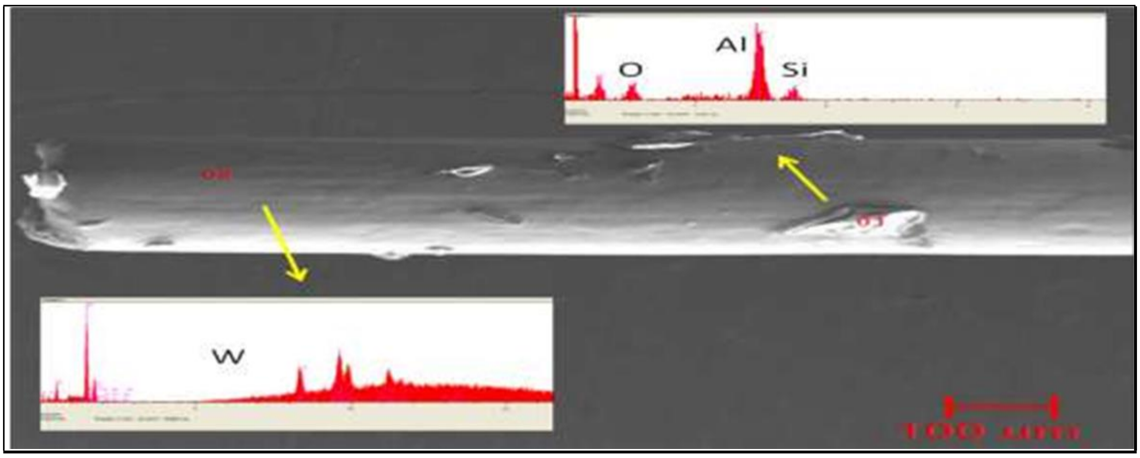

Figure 5. Micrograph of the electrode 35W HID bulb obtained after rupture of the glass structure of the lamp. Chemical analysis by X-ray indicating the nature of the filament surface, which consists of tungsten, as well as the composition of the particulate material cast on the filament, composed of aluminum, silicon, and oxygen.

4. Forensic Application

Despite the promising set of results present herein, it is noteworthy that the effectiveness of the methodology employed for analysis of actual traffic accidents is directly related to the preservation of the accident site, as well as to the number of tests carried out on the automobile. The forensic scientist must test the operation of the security systems regarding traffic, namely brakes, steering, and electrical parts, on a routine check. If the presence of any headlight or flashlight with signs of fracture is found, they should be removed from the vehicle before the electrical tests. This is because when the vehicle electrical system is operated for examination of the electrical component, the scientist may erroneously energize the target bulb, thereby producing undesirable traces, such as mergers, oxidations, and breaks, that do not belong with the original accident.

5. Conclusions

Taken together, our results have enabled establishment of a methodology for verification of whether light bulbs were energized during episodes of headlight rupture due to simulated collision conditions or trampling. Despite the different mechanisms of operation and electrical components, all the automotive headlights studied here originated the same kind of trace when the walls of the bulbs were fractured during their operation. Indeed the glass fragments produced on the fractured surface contained fused metal components (filaments and electrodes) of the bulbs as a result of the due to high temperatures, and these components deposited on the surface. The elementary chemical nature of these remains can be readily determined by X-ray analysis, performed in conjunction with scanning electron microscopy. The absence of previous treatment stages for sample plating (gold or carbon deposit by the sputtering process) allows for the fast and reliable analysis of these traces, thus providing valuable information for clarification of traffic accidents.

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