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A Comparative Study of the Applicability of the Scanning Electron Microscope and the Light Microscope in the Examination of Vehicle Light Filaments

It is generally conceded that, under ideal circumstances, the best source of information regarding the sequence of events surrounding a vehicular accident lies in accurate, complete, and absolutely reliable eyewitness accounts. When, however, as is most often the case, eyewitnesses are missing or the information which they provide is incomplete or conflicting, it is necessary to rely upon data derived from the evaluation of physical evidence recovered from the accident scene and from the vehicles themselves. Evidence of this kind is likely to include glass, paint, soil, fractured metal surfaces, and, frequently overlooked, headlight and taillight filaments, the microscopic examination of which provides information relating to the operating condition of the vehicles' headlights and taillights before, during, and after the accident.

For the examination of headlight and taillight filaments, the Wisconsin State Crime Laboratory has in the past used a light, or optical, microscope. Results have been satisfactory. When, however, the laboratory recently received a grant through the Wisconsin Council on Criminal Justice to explore the forensic applicability and uses of the scanning electron microscope (SEM), it was decided that one of the questions to be explored would be whether, and to what extent, the superior magnification and resolution of the SEM could provide data in this area unobtainable by use of the light microscope. This study was undertaken, therefore, to compare and evaluate results derived from the examination of burned out vehicle headlight and taillight filaments by means of a scanning electron microscope, as opposed to an optical microscope, and to compile a set of reference photographs.

The scanning electron microscope used was a Jelco JSM-U3 equipped with a Polaroid camera, an Ortec energy dispersive X-ray detector, and a Northern Scientific NS-880 computer-based data-handling system. An American Optical Model K-1567 comparison microscope was used for the optical work.

The photographic film used on the SEM was Polaroid Type 55 P/N, ASA 100, and, on the comparison microscope, ASA 320 Kodak Tri-X. All photographs were printed from 4 by 5-in. negatives and the magnifications cited hereafter refer to a 4 by 5-in. print.

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The total number of filaments examined was approximately 50, with roughly half used and half new. Some of the old headlights examined were from a 1969 Chevrolet Impala, a 1969 Chevrolet Chevelle, and a 1971 AMC Matador station wagon; all were original equipment. The new headlights were Tung-ston brand. Table 1 illustrates the variety of conditions examined. The glass was broken by smashing the headlights with a hammer while they were still attached to the automobiles.

TABLE 1—*Variety of conditions examined.*

Head Lamp	Glass Envelope	Filament
new	not broken	not broken or burned out
new	broken	burned out at breaking of glass
new	broken	turned on after breaking of glass
old	not broken	not broken or burned out
old	not broken	burned out normally
old	broken	burned out at breaking of glass
old	broken	turned on after breaking of glass

Normal Burnout

Filaments which burn out in normal use with no oxygen present exhibit a break which has a blunt but rounded or ball-shaped bead of metal (Fig. 1), or a necked-down tip which is smooth at the end (Fig. 2), depending upon the time interval during which the burnout occurs. There should be no glass particles adhering to it.

Impact Failures When Hot But Not Exposed to Air[3]

Hot filaments which are broken by mechanical impact, but not exposed to air while hot, display one of the following characteristics:

1. A ductile fracture at the broken end (Fig. 3). This fracture is caused by mechanical stress. There will be some necking of the filament and the broken end will be separated into many small pieces which are oval or flattened in cross section. The tips of these pieces will often display small cups or "dimples" which are characteristics of an overload ductile fracture. It should be noted that a cold ductile fracture can also occur in a new filament which has not been embrittled by heating. This condition is unlikely to be encountered except in a new original or replacement lamp. If there is any doubt, a portion of the filament can be broken to determine if the fracture is ductile or brittle.
2. A blunt but rounded or ball-shaped bead. As the hot filament distorts, leading to the necking down or stretching out of the filament, the decrease in diameter increases the resistance to current flow and the temperature rises. A sufficiently high rise in temperature will melt the metal filament. This process, which combines mechanical stress with melting, would be difficult if not impossible to distinguish from normal burnout. The filaments may or may not show distortion, but will not exhibit discoloration or oxidation (Fig. 4).

[3] The term "impact failure" relates to the high inertial forces present in an accident. These forces are much stronger than the shocks encountered in daily driving.

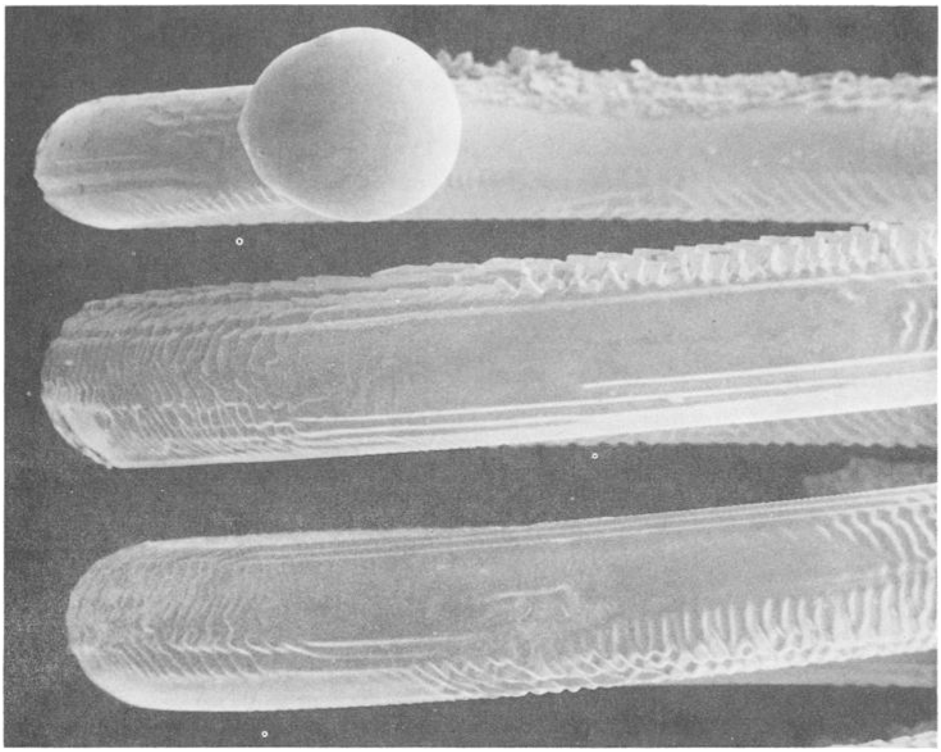

FIG. 1—*Old filament which has undergone normal burnout, SEM, original magnification ×100.*

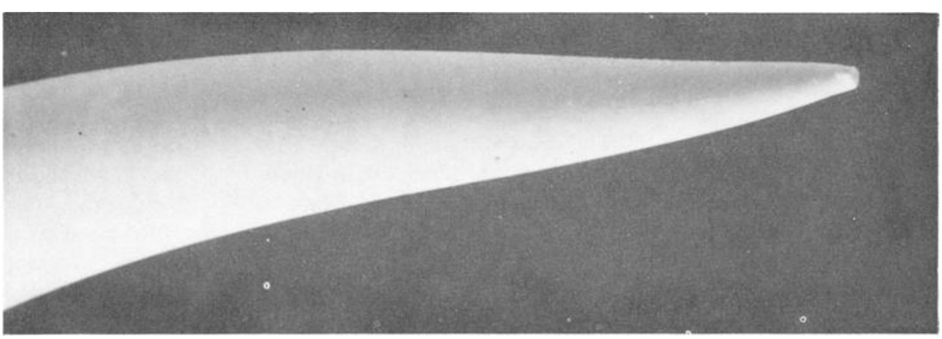

FIG. 2—*Old filament which has undergone normal burnout, SEM, original magnification ×500.*

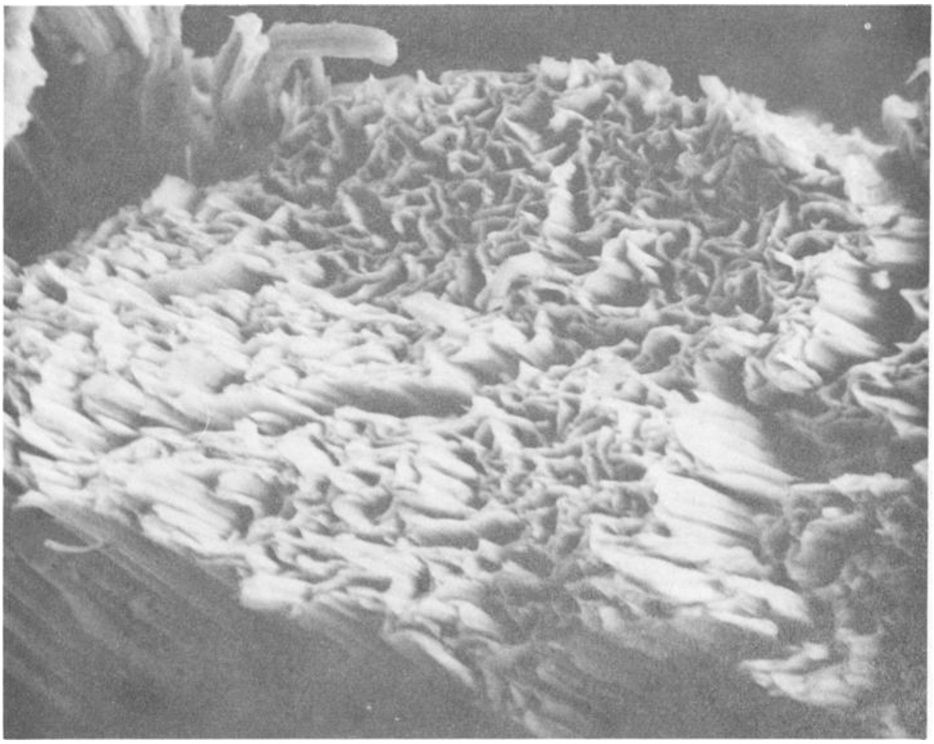

FIG. 3—*Ductile fracture of a hot filament caused by impact failure which did not break the vacuum, SEM, original magnification ×3000.*

Impact Failures When Hot and Exposed to Air

When the glass envelope is broken and the hot filament exposed to air (Figs. 5 and 6), the following physical characteristics will be noted.

1. The contact of the hot filament with air results in rapid burnout with considerable oxidation and discoloration. The vaporization of tungsten oxide will leave a heavy deposit on the headlight reflector above the filament. On those headlights consisting of dual filaments, the filament which was off may also be coated with tungsten oxide.
2. Pieces of glass may be welded onto the filament, and often a bead of fused glass will be found on the coil (Fig. 7). The headlight which sustains a direct hit, breaking both the glass and filament, will be severely distorted and discolored and will have fused glass on it.
3. In the broken area the filament will have a teardrop (Fig. 8) or ball-shaped (Figs. 5 and 6) appearance. The ball-shaped type is slightly elongated and is readily distinguishable from the bead formed by a normal burnout. Also, of course, the normal burnout will lack any debris or oxidation.

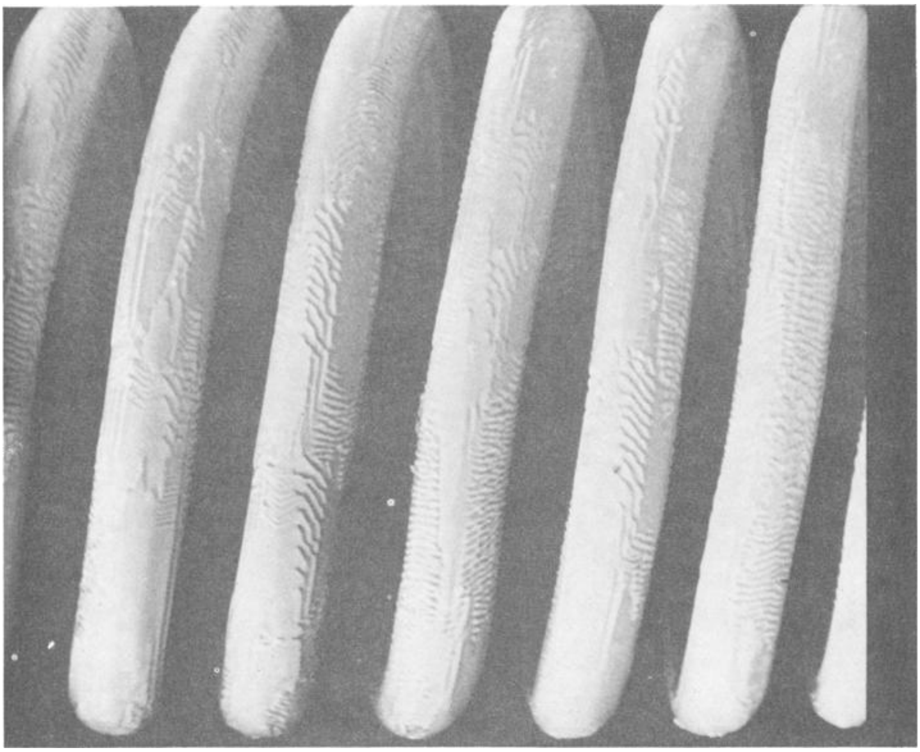

FIG. 4—*Filament resulting from an impact failure which did not break the vacuum, SEM, original magnification ×120.*

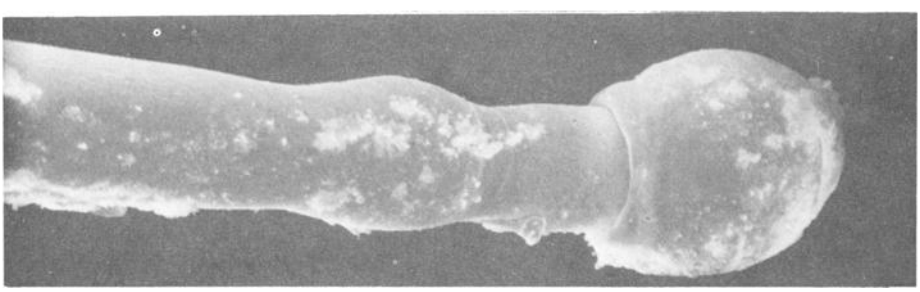

FIG. 5—*Old filament which underwent an impact failure and exposure to air, SEM, original magnification ×100.*

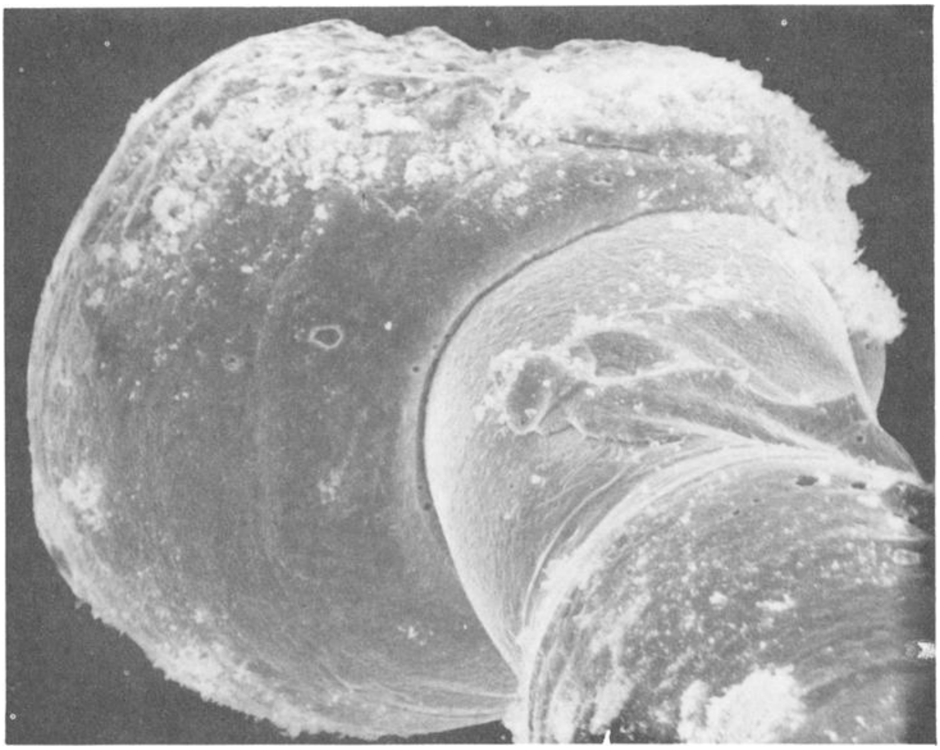

FIG. 6—*Closeup of ball-shaped bead from Fig. 5, SEM, original magnification ×1000.*

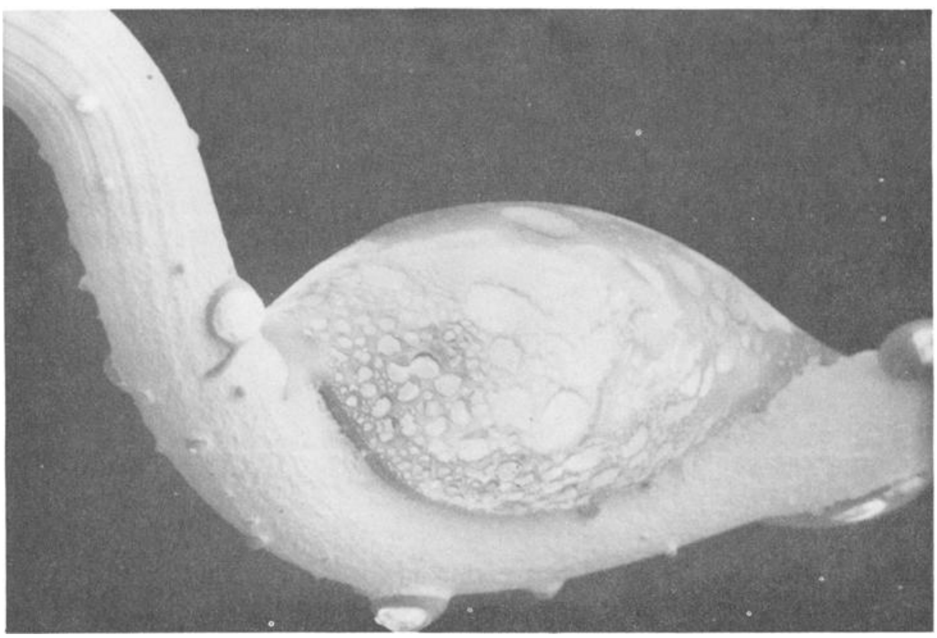

FIG. 7—*A chip of glass which has been fused onto a new filament, SEM, original magnification ×100.*

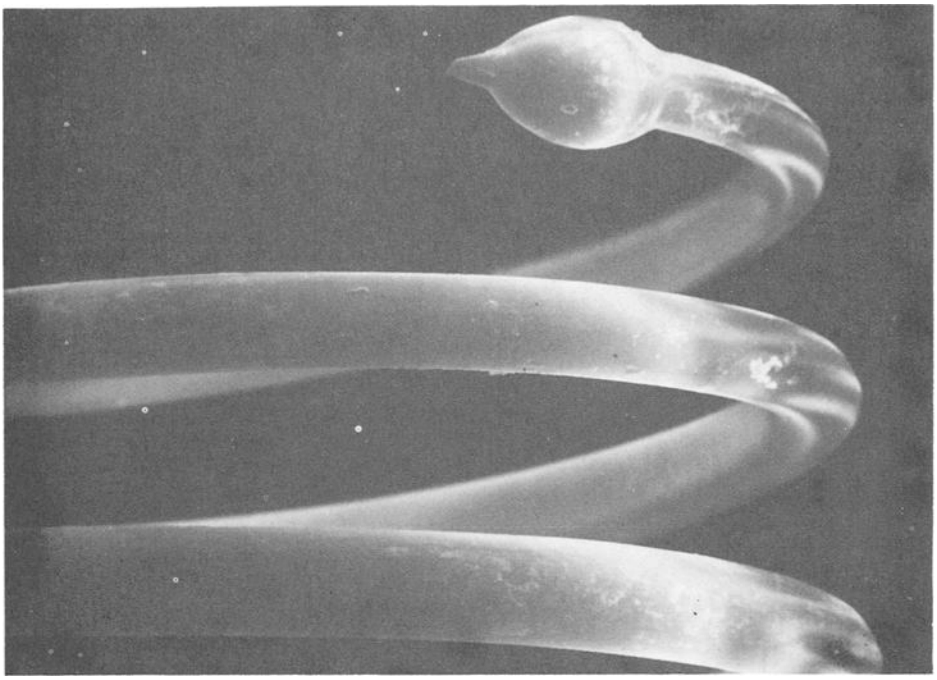

FIG. 8—*Characteristic teardrop end formed when filament suffered impact failure while burning, SEM, original magnification ×100.*

Filaments Broken While Cold

An embrittled filament broken while cold displays none of the characteristic features of hot failures. Oxidation will be lacking and the fracture will be brittle (Fig. 9), with no necking or distortion.

The filament may be broken often into many pieces, if impact is direct. Each piece will exhibit a brittle fracture, and, if the pieces are subsequently fitted together, the shape of the coil should not be distorted.

As mentioned before, a nonembrittled filament will show a ductile fracture.

Filament Turned On After Breaking of Envelope

When a filament is turned on in air it becomes heavily oxidized, and both filament and surrounding glass become discolored.

The filament also necks down to a tip which is blunt and rough at the end (Fig. 10), and may show a small amount of distortion. The entire filament should be attached to the terminal posts of the headlight.

Results are summarized in Table 2.

Conclusion

For viewing some of the physical properties of a questioned filament, an optical microscope is adequate. The presence of discolorations, oxide powders, glass beads, and

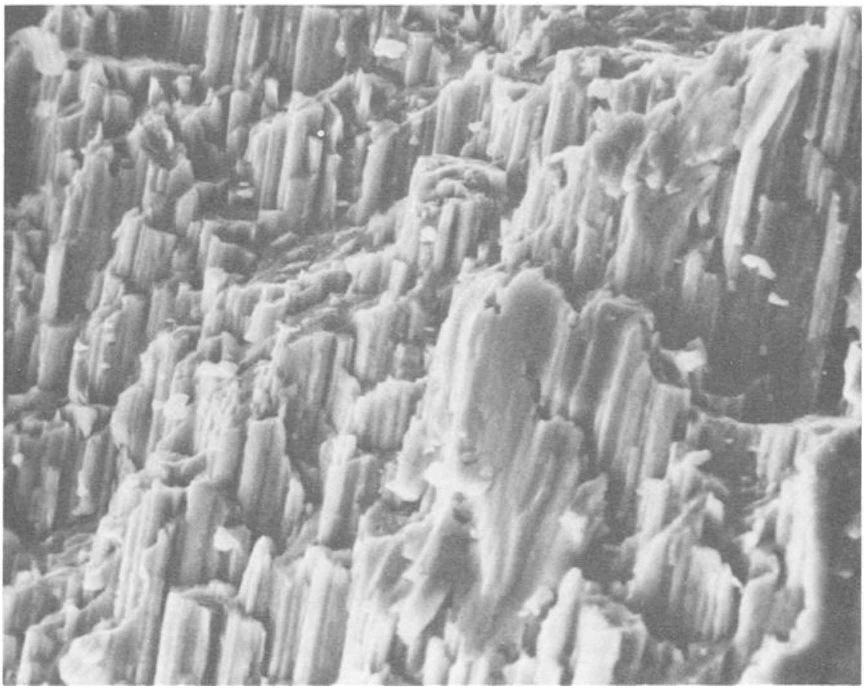

FIG. 9—*Brittle fracture of a cold filament, SEM, original magnification ×3000.*

TABLE 2—*Appearance of filament.*

Event	Filament Condition	Glass Envelope Broken	Distortion	Discoloration	Appearance of Break	Molten Glass
normal burnout	hot	no	no	no	smooth tip, or blunt but rounded	no
impact	hot	no	may exhibit or may not	no	smooth tip, or blunt but rounded, or ductile	no
impact	hot	yes	yes	yes	teardrop	yes
impact	cold	no	no	no	brittle[a]	no
impact	cold	yes	may exhibit or may not	no	brittle[a]	no
after impact	off, then on	yes	may exhibit or may not	yes	necked down and rough	no

[a]May be ductile if filament has not been embrittled (see text).

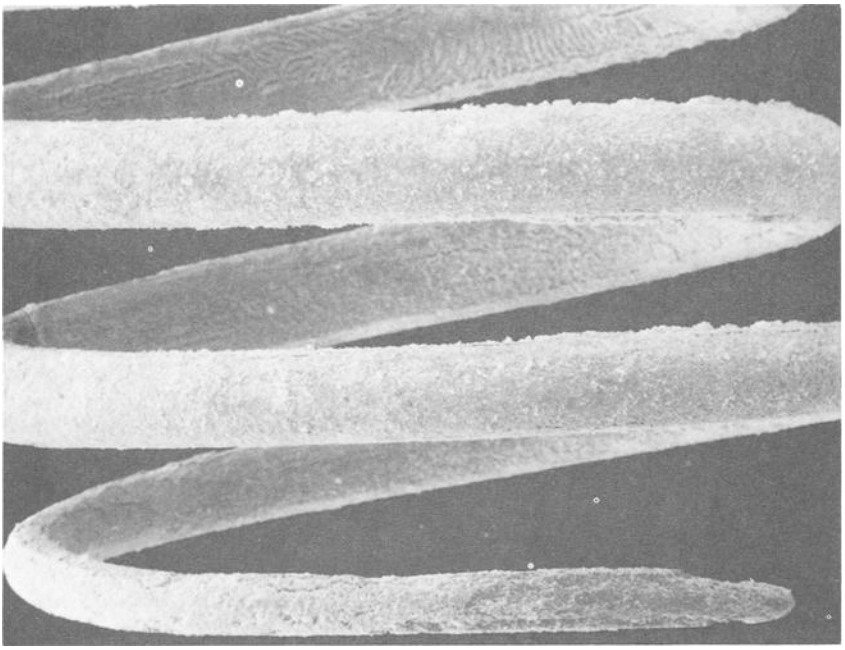

FIG. 10—*A filament which was turned on after being exposed to air, SEM, original magnification ×100.*

the general characteristics of the broken ends are all readily visible at low magnifications. The filament or entire headlight may be hand held or mounted on a steady base. If, however, glass beads are not present and discoloration is slight, the condition of the broken ends will be more heavily relied upon in the formation of an opinion as to the type of failure encountered. When those ends are examined at higher magnification on an optical microscope, the decreased depth of field and small viewing area make it impossible to visualize the entire tip. The continued raising and lowering of the focus and lateral moving of the sample do not allow for the necessary critical viewing of the surface of the tip.

With the electron microscope, color discrimination is lost, and the sample must be small enough in size to fit into the instrument's vacuum chamber. This latter requirement may entail removal of the filament from its mounting. Even without colored images, the glass beads are recognizable, and can be elementally characterized by X-ray fluorescence analysis.

The real advantages of the SEM lie in its larger viewing area, its increased depth of field, and the larger possible magnifications. These points are illustrated in Fig. 11 and 12, which show equal magnification optical and electron photomicrographs of two filaments. In the example cited above, where the critical examination of the broken ends is necessary, only the SEM can show the entire bead and its surface topology.

It is evident from the work done in the study that a combination of a low power (×10 to ×30) optical examination followed by a higher power (×100 to ×1000) electron imaging will yield detailed knowledge about the condition under which the filament was broken.

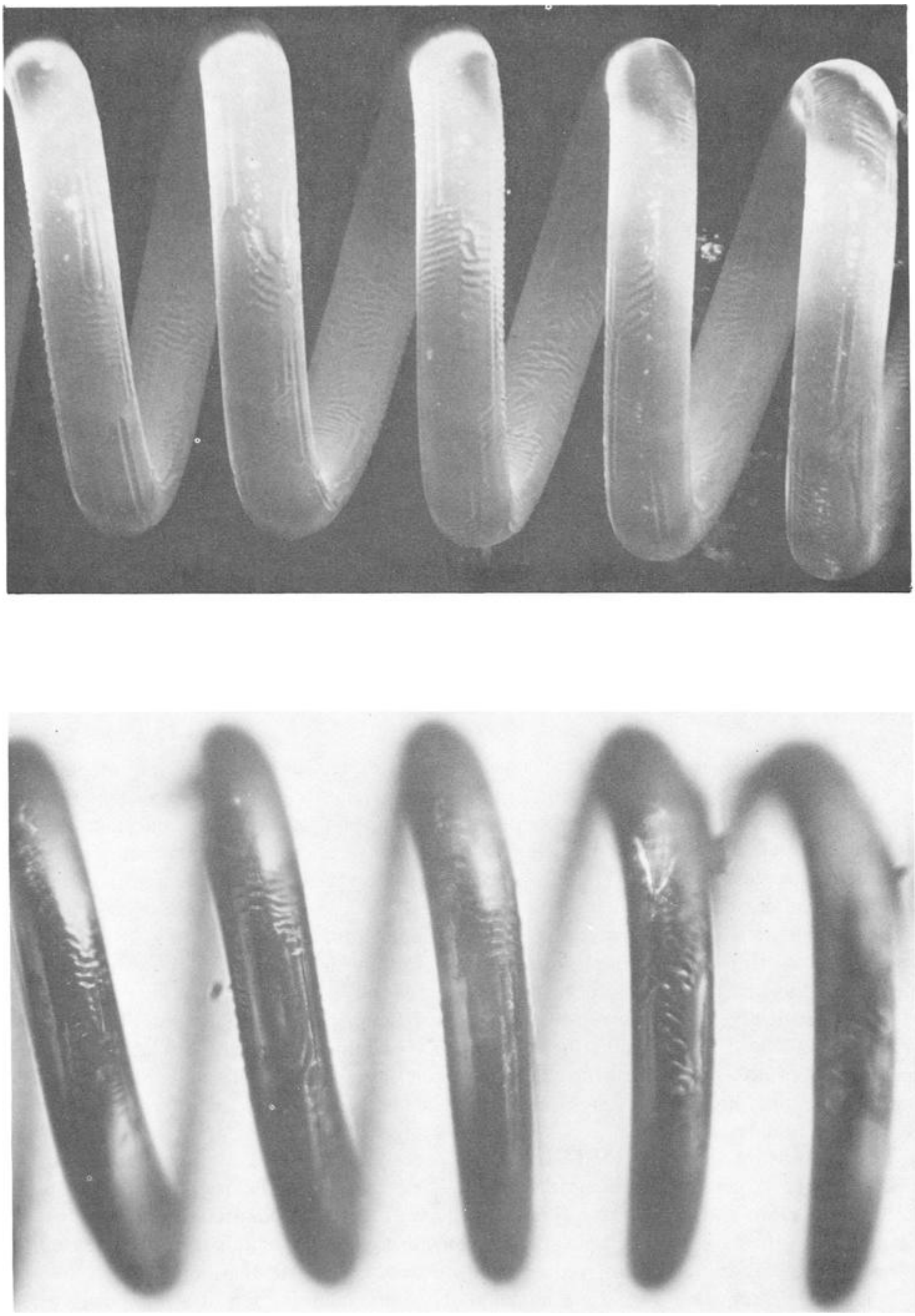

FIG. 11—*Two views of a filament which was not operating when broken (original magnification ×100)*: (top) *SEM and* (bottom) *optical microscope.*

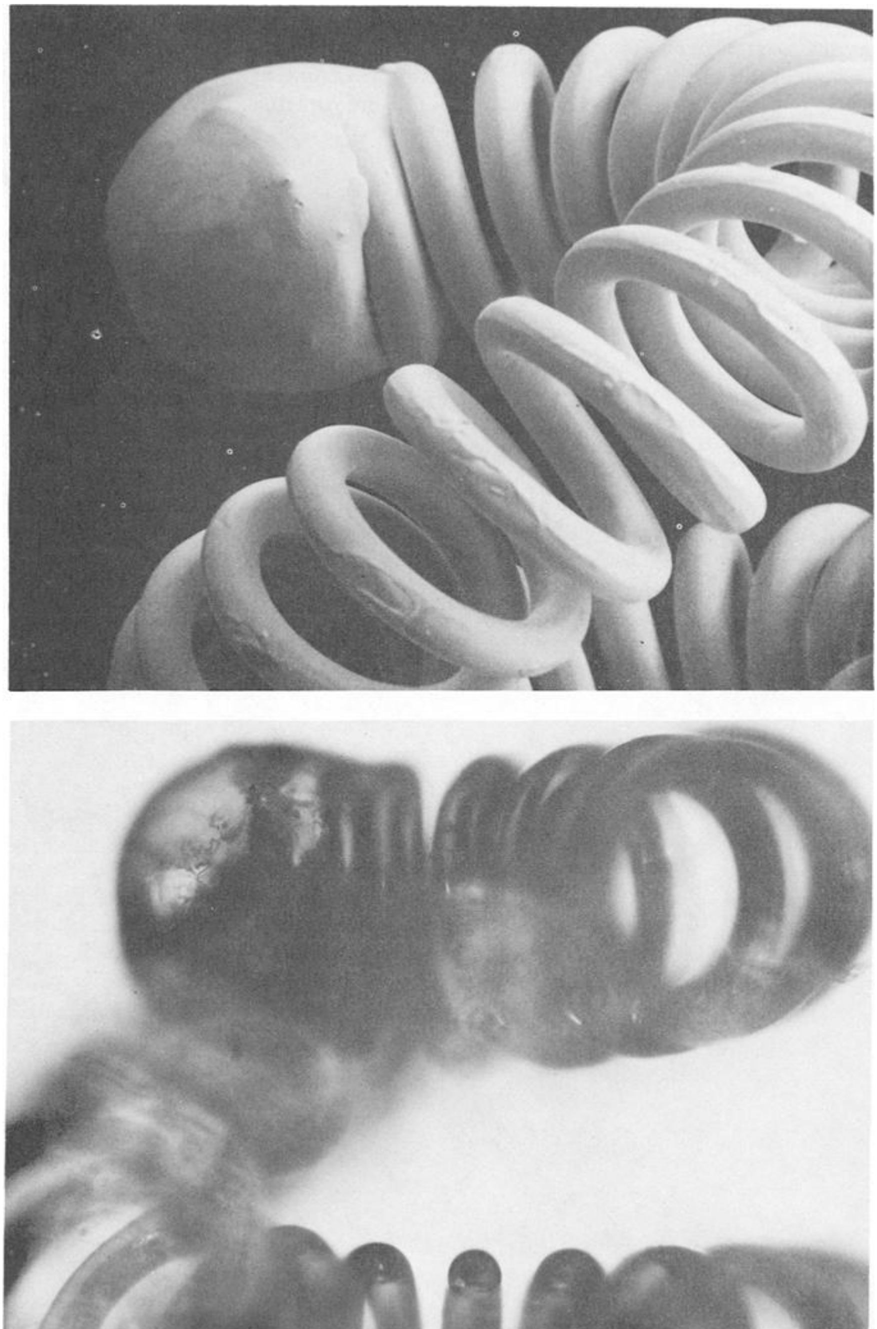

FIG. 12—*Two views of a filament, including its broken end, which was exposed to air while operating (original magnification ×100)*: (top) *SEM and* (bottom) *optical microscope.*

As mentioned earlier, the round bead resulting from an impact failure which did not break the glass envelope may be mistaken for a normal burnout. This could lead to the incorrect conclusion that the headlight was not functioning at the time of the accident. Additional studies must be undertaken to determine whether there are other ways to distinguish these two conditions.

Acknowledgments

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