CASE REPORT

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A Particular Case of Oxidation Colors on Bulb Filament After a Car Crash

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ABSTRACT: Particular oxidization colorings have been observed after an accident on a filament coil from a Philips type R2 bulb (European type front light). Laboratory tests have been performed in order to try to reproduce these oxidization colorings. The most probable hypothesis is that one of the front lights was flashing just before the accident. As far as we know, such a case has not been reported previously in the literature.

KEYWORDS: forensic science, oxidation colors

Case Report

A traffic accident that occurred during thick, foggy November weather in the region of Grenoble (France) required the help of a forensic laboratory in order to define the responsibility of the two involved motorists.

A Peugeot model 205 XAD driving at a speed of 42 mph (≈18 m/s) crashed, without slowing, into a heavy truck trailer coming from a cross road. Visibility at that moment reached roughly 50 m. The collision was particularly violent (Fig. 1). The truck driver who had not obeyed the stop sign said he had not seen the coming car. The 32-year-old female car driver, seriously injured, when questioned, after a three day coma, told the investigators she had indeed turned on the lights of her vehicle but couldn't recall which ones.

FIG. 1—*Peugeot 205 XAD car after crash.*

Examinations

The Philips R2 bulb (European headlight) from the front right optical set was submitted to the laboratory for analysis. This bulb

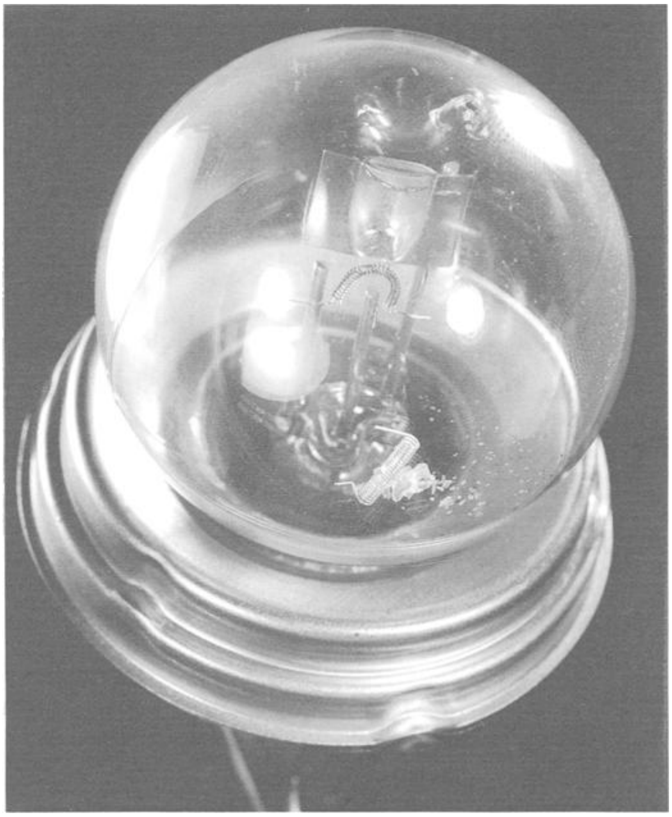

FIG. 2—*Philips R2 bulb (European headlight) from the front right optical set.*

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still had its glass bulb, but a small half millimeter hole could be seen at the top (Fig. 2). Several glass particles were within the bulb. The high-beam filament coil was still attached on its original support while the low-beam filament coil was broken at its two extremities and it laid free in the bulb.

Microscopical examination of the R2 bulb showed that:

- no tungsten oxide deposit could be found within the bulb,
- no deformation nor oxidation coloring could be seen on the broken low beam filament coil,
- the high beam filament was intact despite a slight incline in its curvature, (Fig. 3).
- a slight iridescent oxidization coloring had occurred on the central part of the high beam filament coil (Fig. 3).

The scanning electron microscopy of low-beam filament coil clearly revealed brittle fractures of transcrystalline type (Fig. 4) (4,5).

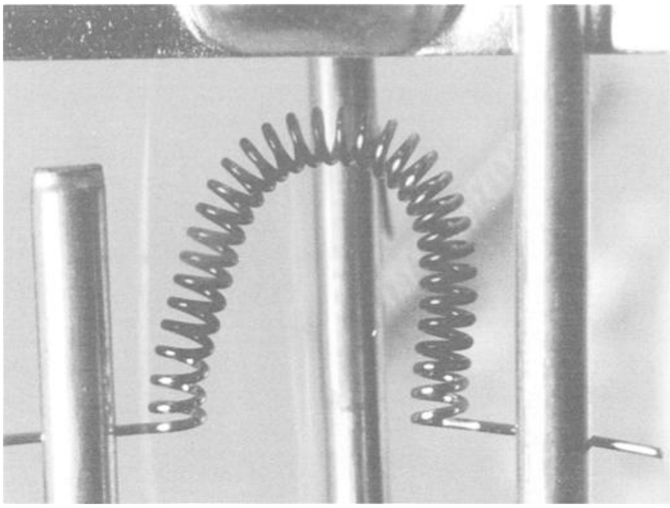

FIG. 3—*Iridescent oxidization coloring on the central part of the high beam filament coil.*

Discussion

Incandescent light bulb filaments are made of tungsten. This element belongs to a family of materials which exhibits a physical change above a certain "transition" temperature which is, in this case, between 200°C and 400°C (4). Thus, below 200°C, the tungsten filament is brittle. Above 400°C, it becomes ductile, which means it can be stretched (plastic deformation) to a certain point without breaking. Concerning European type head-lights, the lighted filament coil operates at a temperature of 2500°C.

Tungsten is chemically stable in air at low temperature, oxidizes easily above 600°C and melts at 3410°C. In case of bulb breakage, the oxygen in the air will be able to react with the filament only if it is "hot." On its surface, the tungsten filament coil changes into different tungsten oxides which give annealing coloring with several graduations (WO_3 yellow, $WO_{2.9}$ dark-blue, $WO_{2.72}$ reddish-violet, WO_2 brown (4)). In the case of a functioning filament ($\approx$2500°C), the coil will blacken. Tungsten oxide can also redeposit on the cold areas of the bulb as fine particulate deposits, ranging in color from white to yellow.

Different tests were performed on R2 type light bulbs which had an identical hole at the top of the glass bulb. These tests consisted in supplying electrical power to such bulbs for a short duration or until the bulb ceased operation (burned out). It was shown that the filament coil had only a 20 second to 2 minutes life expectancy, depending on the conditions of the bulb test (see Table 1).

A few seconds after applied voltage and after the blackening of the filament coil and the deposition of some fine particulate tungsten oxide, yellow tree-like tungsten oxide groths appear on the two high-beam filament coil extremities (Fig. 5). Narrowings of the filament coil can also be observed in certain cases (Fig. 6). The filament coil fracture occurred near one of its ends (hardly visible on photo 5 because it is hidden by the groths). This fracture was studied via a scanning electron microscope (Fig. 7). It has a rounded shape and it shows under higher magnification a very peculiar surface appearance (Fig. 8). This could be by tungsten recrystallization, which can occur at a temperature very close to the melting point.

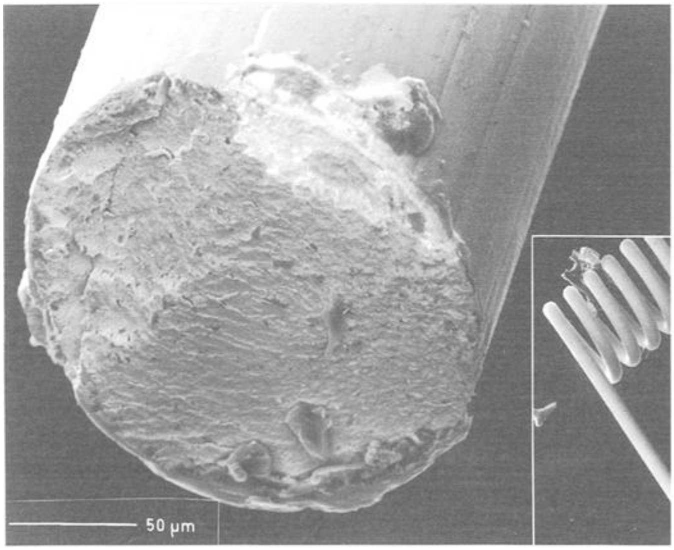

FIG. 4—*Clear brittle fracture of transcrystalline type of the low-beam filament coil.*

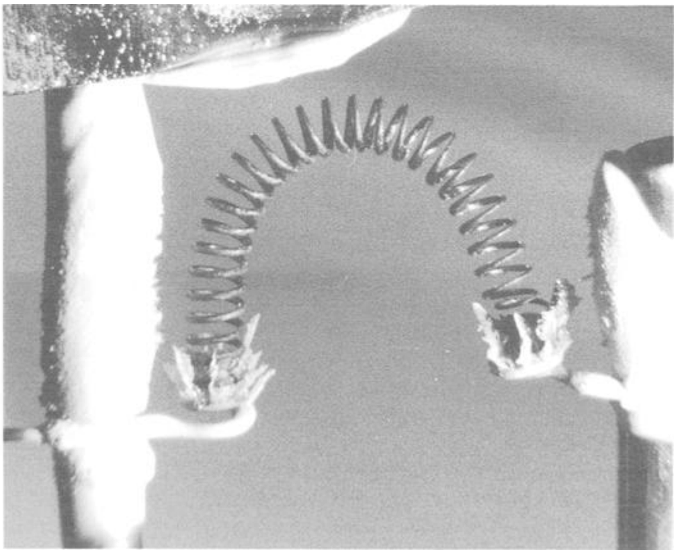

FIG. 5—*Yellow tungsten oxide tree-like groths on the high-beam filament coil (test #2).*

TABLE 1—*Bulb filled in with room pressure air ($^{1}/_{2}$ mm diameter hole on the glass bulb).*

	Power conditions	Filament type	Power electric duration	Results	
				filament coil	other observations
Test 1	12,8 V 2 A	low-beam	0.5 s	blackening	whitish fine particule deposition on glass, support posts and reflector
Test 2	5 V 2 A	high beam	up to the filament coil rupture (32 s)	blackening, yellow tungsten oxide groth on the coil extremities spirals, narrowing of the filament coil diameter	whitish fine particule deposition on glass, support posts and reflector
Test 3	12 V 4 A	high beam	up to the filament coil rupture (20 s)	blackening, yellow tungsten oxide groth on the coil extremities spirals and support posts, narrowing of the filament coil diameter	whitish fine particule deposition on glass, support posts and reflector
Test 4	5 V 2 A	high beam (new bulb)	up to the filament coil rupture (2 mn 30 s)	blackening, yellow tungsten oxide groth on the coil extremities spirals and support posts, narrowing of the filament coil diameter	whitish and *bluish* fine particule deposition on glass, support posts and reflector

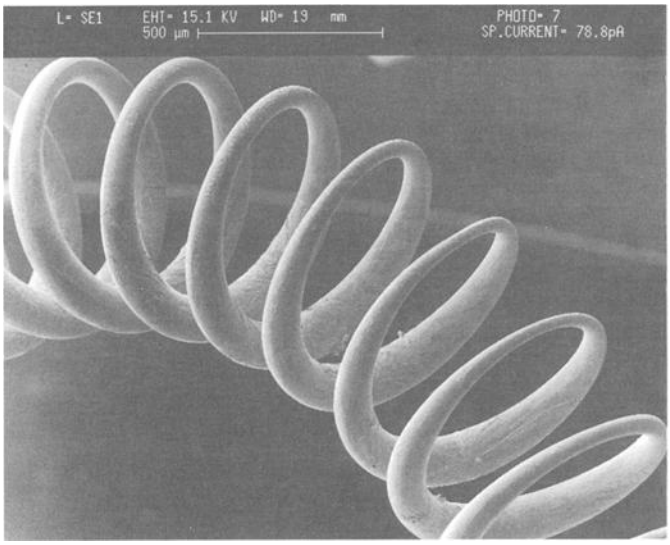

FIG. 6—*Narrowing areas on the high-beam filament coil viewed by S.E.M. (test #2).*

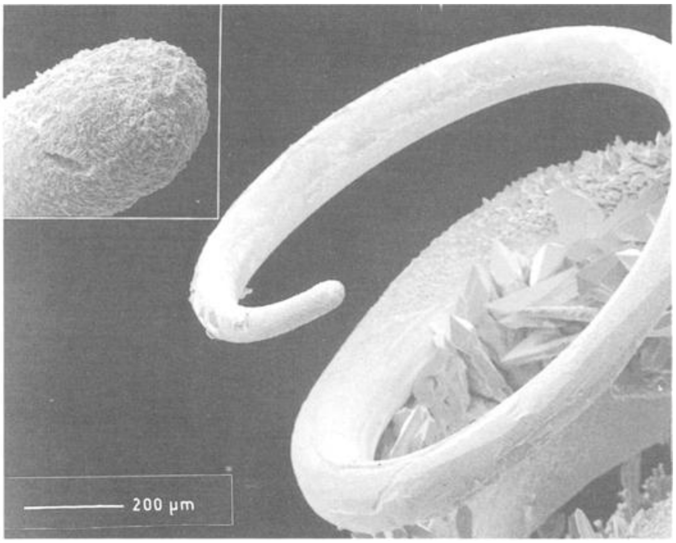

FIG. 7—*Fracture of the high-beam filament coil viewed by S.E.M. (test #2).*

It is thus reasonable to believe that the hole at the top of the bulb was caused by the crash. However, if this is not the case (a pre-crash hole exists), the lights could not have been turned on during or after the crash. Furthermore, since no deposit can be seen on the glass bulb, the hypothesis that the hole was present before the crash is rejected.

The observations regarding the low-beam filament from the Philips R2 bulb are as follows: no deformation, no visible oxidization, brittle fractures when "cold" (SEM). Accordingly, we can then conclude with confidence that the filament coil of the low-beam was turned off at the time of the accident.

The high-beam filament coil shows a slight deformation only, not typical at all of a functioning filament which has undergone a violent shock. However, this very slight increase in its curvature cannot be traced to the manufacturing process. In fact, as it stands, the filament could not have allowed the correct centering of the bulb during the flange assembly and the bulb would have been immediately rejected. Two hypothesis can be made to explain this observation. First, the deformation may be due to constant vibration (or slight shock) due to road irregularities while the filament coil is functioning. Secondly, it may come from a more violent shock to a cooling filament which was recently turned off but which is near the transition temperature.

The high-beam filament coil also shows a slight oxidization, although not very important, this cannot be neglected. The oxidization colors are the same as the ones observed on a filament coil that was not functioning at the time of the bulb breakage but that would have been heated by the incandescence of another filament (3). For a R2 type bulb, the performed tests did not yield such oxidization colors on the high-beam filament coil (see Table 2). This is very likely due to the reflector presence which shields it from radiant heat. Anyway, this explanation is problematical

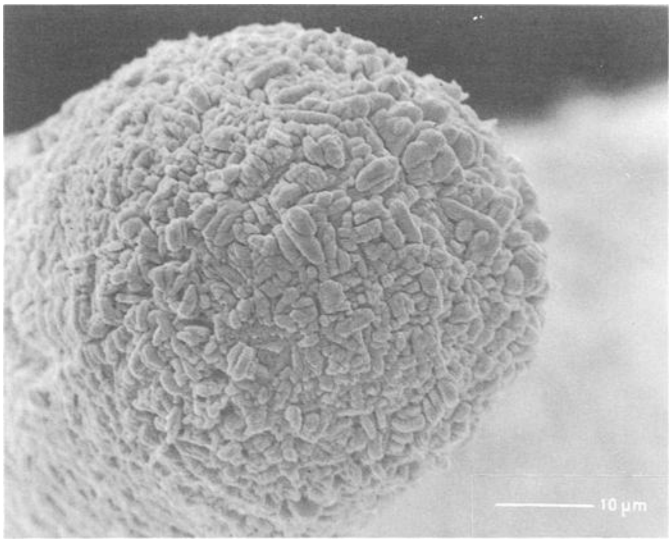

FIG. 8—*Peculiar surface appearance of the fracture viewed by S.E.M. (test #2).*

because we have already concluded that the low beam filament was off.

A series of tests were performed (Fig. 9) at the Philips manufacturing center laboratory in Chartres (France) in an attempt to reproduce this type of oxidization (see Tables 3 and 4). For interpretation, it is important to remember that the R2 type bulb filament (diameter 170 μm) reaches its functioning temperature in roughly 0.05 second and cools down from 2500°C to 200°C in roughly 2 seconds (1,4).

This observed particular oxidization is obtained when any oxygen supply is available to a cooling filament, but only if the bulb itself is not too hot. In fact, the R2 bulb originally has a lower than atmospheric pressure inside (0.7 atm of a N_2-Ar mixture). If the bulb functions long enough (more than one minute), the inside pressure raises above one atmosphere. If a small hole occurs on the bulb during cool down, it is not the outside oxygen that first enters the bulb but instead the bulb atmosphere escapes. The performed tests show there is no oxidization of the high-beam filament coil (Fig. 10, tests 12 & 13 on Table 4). If the filament is functioning for a short time (only a few seconds maximum), the inside atmosphere of the bulb cannot heat and the inside pressure remains lower than that outside. If a small hole occurs in the protective

TABLE 2—*Air exposure after power interruption of the low-beam filament coil (reference time t_0: power interruption).*

	Power conditions	Power electric duration before t_0	Delay between t_0 and air exposure	Results: filament coils: low-beam filament	Results: filament coils: high-beam filament	Results: other observations
Test 5	12 V 2 A	1 mn	0.5 s	blackening	none	whitish fine particule deposition on the reflector
Test 6	12,9 V 3,2 A	5 mn	0 s (power interruption and simultaneous air exposure)	oxidization colorings (yellow or reddish violet) all along the filament coil	none	yellow-golden oxidization on the reflector

TABLE 3—*Air exposure before power interruption of the high beam filament coil (reference time t_1:* air exposure).

	Power conditions	Power electrical duration before t_1	Delay between t_1 and power interruption	Results: Filament coil	Results: other observations
Test 7	12 V 2 A	0 s	0.5 s	blackening	none
Test 8	13,1 V 4 A	2 min	5 s	oxidization colorings (yellow or reddish violet) all along the filament coil	slight yellow-golden oxidization on the reflector
Test 9	12,7 V 4 A	3 min	3 s	oxidization colorings (reddish violent and brown) all along the filament coil	slight yellow-golden oxidization on the reflector
Test 10	12,8 V 4 A	3 min	1 s	yellow oxidization coloring all along the filament coil	very slight yellow-golden oxidization on the reflector
Test 11	12,8 V 4 A	1 s	1 s	blackening	whitish fine particule deposition on glass, support posts and deflector

TABLE 4—*Air exposure after power interruption of the high beam filament coil (reference time t_2: power interruption).*

	Power conditions	Power electrical duration before t_2	Delay between t_2 and air exposure	Results: filament coil	Results: other observations
Test 12	12,9 V 3,7 A	5 min	0.5 s	none	none
Test 13	13 V 3.6 A	7 min	0.5 s	none	none
Test 14	12,9 V 3,7 A	10 min	0 s (power interruption and simultaneous air exposure)	slight oxidization coloring (yellow) all along the filament coil	very slight yellow-golden oxidization on the reflector
Test 15	12,8 V 4 A	1 s	0 s (power interruption and simultaneous air exposure)	blackening	slight whitish fine particule deposition on glass and support posts
Test 16	12,8 V 4 A	1 s	1s	oxidization colorings (yellow, reddish purple, blue), except on the filament extremities	none
Test 17	12,8 V 4 A	2 s	1s	oxidization colorings (yellow, reddish purple, blue), except on the filament extremities	none

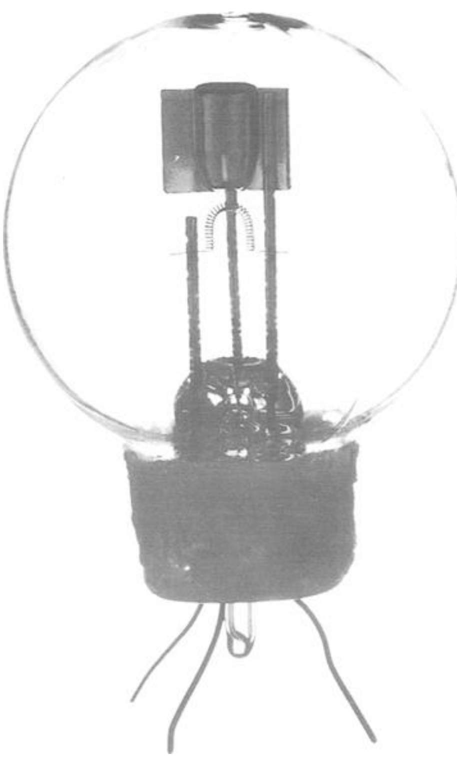

FIG. 9—*Example of bulb used for surveys presented in Tables 2, 3 and 4. Power is supplied by the copper conductors out of the base. The glass tube (Ø ≈ 0.5 mm), once broken, allows air entrance into the bulb.*

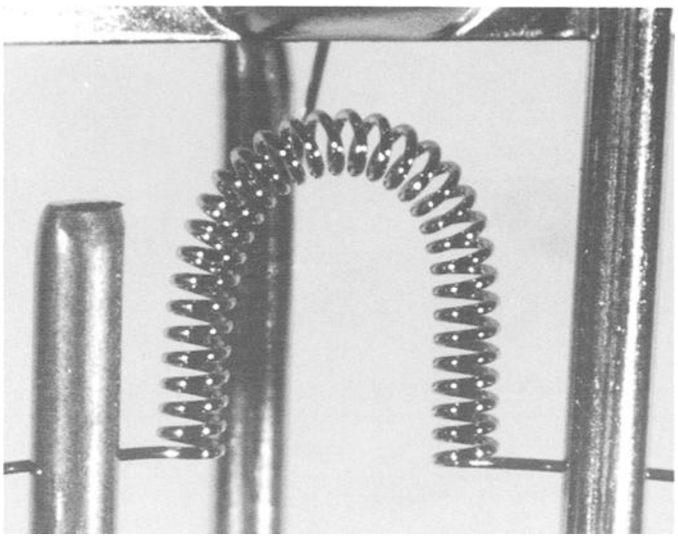

FIG. 10—*High-beam filament coil obtained after test #12.*

glass during the cool down, the air immediately enters the bulb and oxygen produces the observed oxidization (Fig. 11, tests 16 & 17 on Table 4).

Conclusion

The light microscope and the scanning electron microscope examinations of the Philips R2 low-beam filament coil (of the front right optical set) resulted in a conclusion that the filament was not functioning at the time of the accident. The light microscopy on the Philips R2 high-beam filament coil revealed itself to be more complex than originally thought. From the different experiments performed, only one hypothesis is supported. A brief energizing of the filament just before the time of the crash can explain its

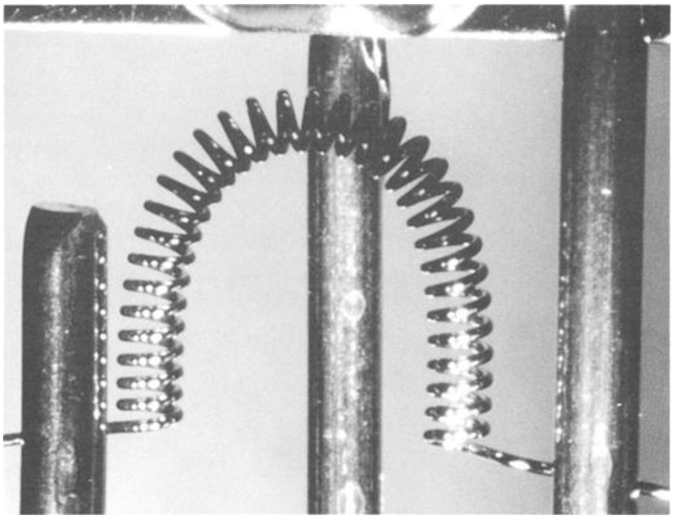

FIG. 11—*High-beam filament coil obtained after test #16.*

specific oxidization. The most probable conclusion is that the high-beams flashed just before the accident.

Acknowledgments

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