Aftermarket LED-based electronic devices, buyer beware

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ABSTRACT

This paper presents a case study involving replacement H4 light bulbs with LED devices purchased from eBay. The product packaging makes several claims, several of which are not met. In particular, the LEDs used are not those indicated on the package. There are significant differences in construction between the LEDs used in the product and genuine LEDs purchased separately from authorized distributors.

Key words: LEDs, light emitting diodes, counterfeits

INTRODUCTION

This work is done in part for the SAE G19A committee. A series of test method documents are being prepared to complement the AS6171 standard [1]. One such document is SAE AS6171/13 Technique for Suspect/Counterfeit EEE Parts Detection by Secondary Ion Mass Spectrometry (SIMS) Test Method [2]. To create relevant examples for the document, it was deemed necessary to provide the comparison of doping profiles between a known authentic part, called an exemplar, and a suspect counterfeit part. A LED emitter is ideal for SIMS analysis because of the planar geometry of LEDs.

To qualify as a suspect counterfeit LED, the brand and type of LED used in the products must be clearly identified and then demonstrated to be a suspect counterfeit. Many products make no claims regarding the source of LEDs used. A suitable product was found on eBay.

DETAILS OF THE PURCHASED PRODUCT

The product chosen for this project is a LED-based replacement H4 headlight. It was readily available, reasonably priced and claimed to contain Luxeon ZES LEDs. There is even a photo of the LED emitter on the package which matches publicity images from Lumileds. The description of the ordered product is shown in Figure 1 and the product received is show in Figure 2.

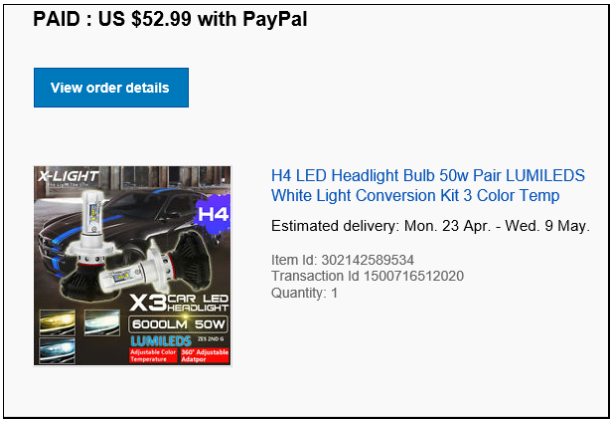

Figure 1. Product ordered, as shown on our eBay account.

Figure 2. Product received**.** The packaging is different but all the claims are identical.

Inside the box were two light fixtures, an instruction manual and a bag containing colored plastic films. See Figure 3.

Figure 3. The contents of the box.

The envelope contains four yellow plastic films and four light blue ones (Figure 4). The color temperature of the LEDs is probably 6500K. The "tuning" of the color temperature is done by covering the LEDs with these films. The yellow filter mimics 3000K while the blue filter mimics 8000K.

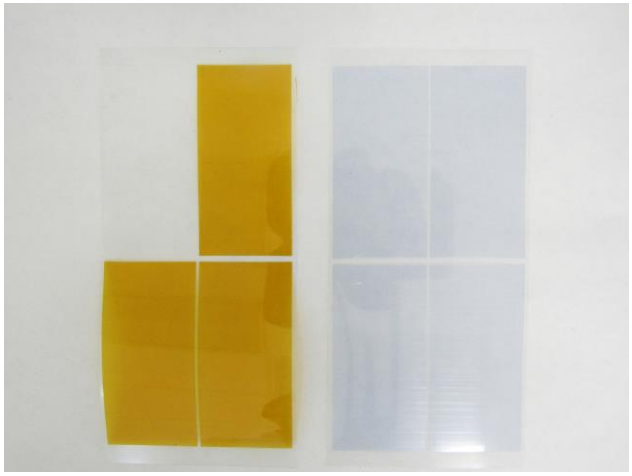

Figure 4. The colored films. One has been removed.

The product specification is printed on one side of the box (Figure 5) and inside the instruction manual. It reads:

Input Power	L/25W, H/25W
Operating Voltage	DC 9-32V
Luminous Flux	L/6000LM,H/6000LM
IP Rate	IP67
Light Source Model	ZES Chip
Color Temperature	3000K/6500K/8000K
Heat Dissipation Theory	Aviation Aluminum 7
Operating Life	>30000hrs
Operating Temperature	-40°C~+80°C

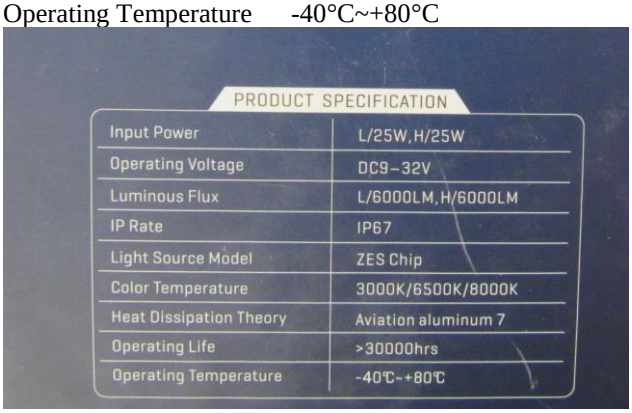

Figure 5. Product specification printed on the outside of the box.

Does this product contain Lumileds Luxeon ZES LEDs? Are there other aspects of this product that we should be concerned with?

PRODUCT DECONSTRUCTION

The first step is to try to light it. Since this is intended for automotive use and is rated DC 9-32 V, this is simple.

Figure 6. Light bulb off and lit.

Deconstruction was also found to be simple. The top cap can be unscrewed, revealing a plastic tube around the LEDs which is meant to accommodate the colored films.

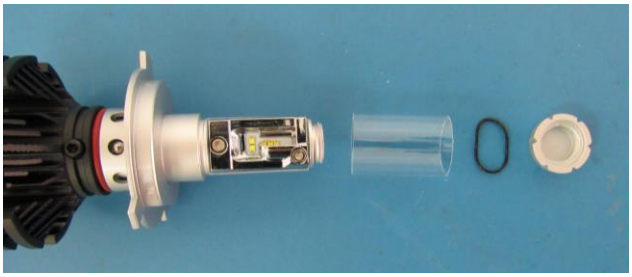

Figure 7. Partially deconstructed light bulb.

With further deconstruction, the reflector was removed and the driving circuitry pulled out of the neck.

Figure 8. Further deconstructed light bulb showing one LED panel. There are two LED panels, one on each side of the bulb.

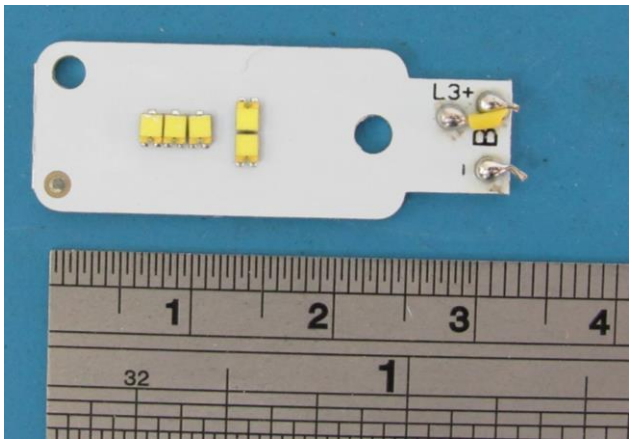

Figure 9. Close-up of a LED panel. It contains five (5) LED emitters.

The LEDs do resemble the LED image on the box but are they the real thing?

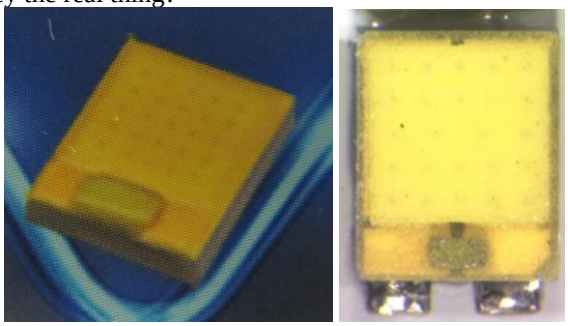

Figure 10. Comparison of the LED photo on the box with the LED in the product. They are similar but not identical.

THE EXEMPLARS

The exemplars used in this project are Luxeon Z (purchased in 2013) and Luxeon ZES (purchased in 2018), both from authorized distributors, Mouser and Digikey. Although the product claims to be a Luxeon ZES, the Luxeon Z was also used as exemplar because it matches the photo on the box. The product LED was compared with the exemplars with phosphor on, phosphor removed, and in X-Ray.

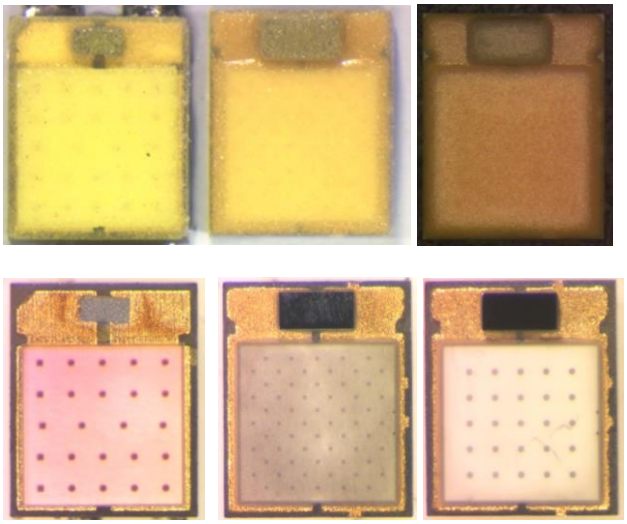

Figure 11. Optical **c**omparison of the product LED with the exemplars. Top row, LEDs with phosphor in place. Note: not all LEDs are of the same color temperature. Bottom row, LEDs with phosphor removed. Left: LED from product, middle: Luxeon ZES, right: Luxeon Z. The small dark spots seen in all three dice are cathode vias, not bumps.

From optical imaging, all three are flip-chip LEDs and the cathode via pattern is different in all three LEDs. Tilted view SEM imaging gives a better perspective of the die itself. In the Luxeon, the sapphire has been removed but it is still present on the product LED.

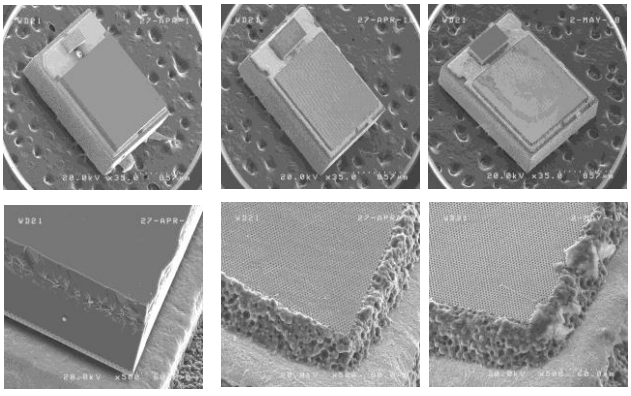

Figure 12. Tilted view SEM images of all three LEDs. (Same positions as in Figure 11).

X-RAY IMAGING

Imaging the LEDs still attached to the panels revealed interesting information regarding the quality of assembly. Several solder pads show no solder under the part, just some on the side wall (Figure 13). One LED has no solder on the thermal pad, and several have no solder under the cathode or anode pads. This is a product that will be submitted to shocks and vibrations in its application. This product is doomed to an early failure.

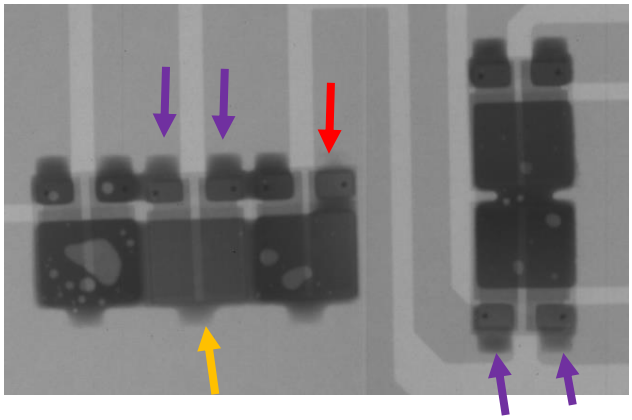

Figure 13. X-Ray of LEDs on the panel. Red arrow: no solder at all on pad. Purple arrows: no solder under device, only on side. Orange arrow: no solder on thermal pad.

X-Ray imaging of a device removed from the panel provides further information regarding the structure of the package. The two genuine Luxeon LEDs have bumps while the product LED has none.

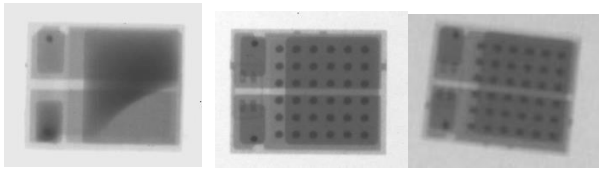

Figure 14. X-RAY images of the three LEDs (Same positions as in Figure 11). The dark spots in array configuration in the Luxeons are gold bumps.

CROSS-SECTION ANALYSIS

The product LED and the Luxeon Z from 2013 were cross-sectioned to investigate the details of the attachment of the LED die to the ceramic package.

The Luxeon die consists of a very thin GaN die (the sapphire has been removed) covered with phosphor particles. It is connected to the copper trace of the ceramic package by gold bumps.

The product LED consist of a GaN on sapphire die, with sapphire still in place, also covered with phosphor particles. It is soldered to the copper trace.

In both cases the GaN layer is approximately 7µm thick.

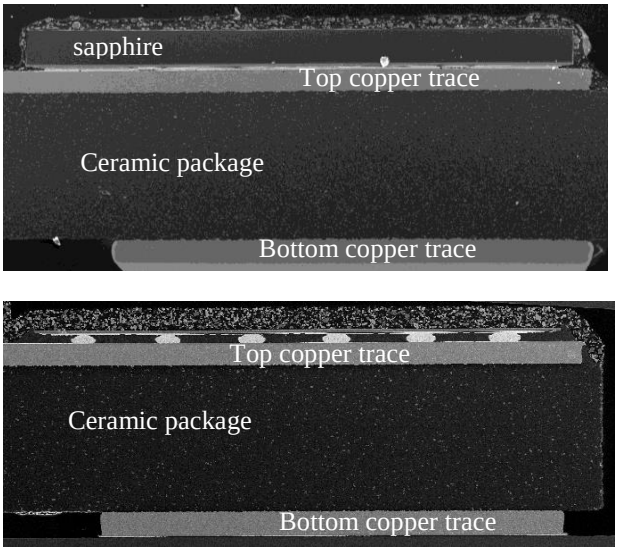

Figure 15. SEM images of the die in cross-section. The top image is of the product LED and the bottom image is the Luxeon Z from 2013. At this magnification the GaN layer is hard to see.

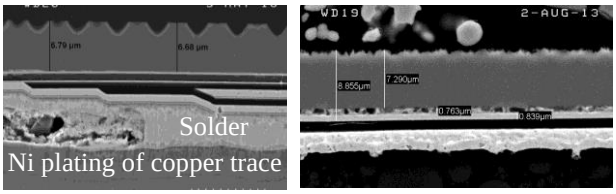

Figure 16. High magnification SEM images of the GaN layers of both LEDs. The left image is of the product LED and the right image is the Luxeon Z from 2013. Both devices have a 7µm thick GaN layer. The growth sapphire layer is still present on the product LED. The product LED is attached to the top copper trace by solder.

DISCUSSION

What about other specifications? What does Heat Dissipation Theory mean exactly? What is Aviation Aluminum 7?

IP67 is an IEC rating. It states that the unit can be dropped into a body of water up to a meter deep for half an hour. This rating is strictly for fresh water. There is no guarantee of protection from submersion in other liquids, salt water for example. This is not an automotive rating.

Will these lamps really emit 6000 lumens? Presumably this means 3000lm/lamp or 300lm/emitter, since there are ten emitters in each lamp. The brightest ZES, according the datasheet [3], emits only 270lm.

CONCLUSION

It is clear that the product LED is not a Luxeon Z. It will be a good candidate for SIMS analysis.

Counterfeit LED-based products are becoming very common. LEDs are special semiconductor devices requiring careful design of the driving circuitry, and attention to the intended environment conditions. Packaging, how the LED die is mounted on a substrate for soldering, is an important factor to consider in view of the intended application. Using the wrong LED type in an application can have disastrous consequences for the product and often for the user.

After market products are relatively inexpensive. Not all after market products are counterfeit, particularly if they do not list a trade-mark. However, many claim specifications that are not met or hard to interpret. Buyer beware.

REFERENCES

1. SAE AS6171 Test Methods Standard; General Requirements, Suspect/Counterfeit, Electrical, Electronic, and Electromechanical Parts. Issued 2016-10-30. https://www.sae.org/standards/content/as6171/

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3. https://www.lumileds.com/products/high-power-leds/luxeon-z-es