

## QUANTIFYING QUALITATIVE ATTRIBUTES OF CORED SOLDER WIRE IN LED LUMINAIRE SOLDERING - PART I

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### ABSTRACT

The LED lighting industry and indeed, the electronics industry, prefers to have "shiny solder joints", indicated by a qualitative visual examination. No metrics exist to quantify "shininess" of the solder joints. This paper presents the concept of reflectivity as a metric to quantify "shininess" of the joint. A novel approach to quantifying "Reflectivity" of solder alloy joints has been developed and implemented.

Reflective properties of assembled solder alloy joints are seldom analyzed. However, in new market applications such as LED lighting, the ability to quantify the reflectivity of alloys can provide greater value. The techniques developed by Alpha are presented in this study allow designers and manufacturers the ability to quantitatively assess aesthetics of the solder joints, impact of flux residue and select materials that provide a performance and cost of ownership advantage.

In this study, differing solder alloys and flux chemistries are examined for their relative reflectivity. Both alloys are assembled under identical conditions to minimize statistical variation. Using a commercially available spectrometer system the alloys are analyzed and compared to a calibrated mirror.

Investigation of solder alloys of dissimilar flux chemistries and alloys reveals a significant reflectivity difference. The methodology of the experiment and results are discussed in this paper.

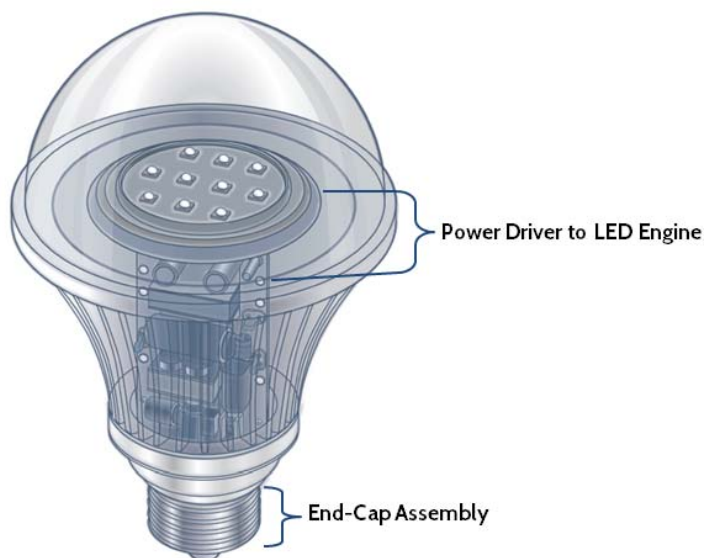
Keywords: LED, Reflectivity, Solder, Cored Wire, Brightness, SAC305

### INTRODUCTION

Solder joints are seldom quantified for their reflectivity properties. Traditionally, solder joints are characterized visually for their "shininess/glossiness". With the emergence of new markets such as the LED industry the implications of quantifying attributes such as solder shine and flux residue by means of reflectivity can provide greater value.

Joints soldered with cored wire are consumed in abundance for many different lighting applications. Most commonly, these spools of solder are used to assemble the connection between the control power driver board to an LED engine array fixture, board to board connections for linear lighting

and serve as the electrical gateway for Edison socket-based bulbs as shown in Figure 1.



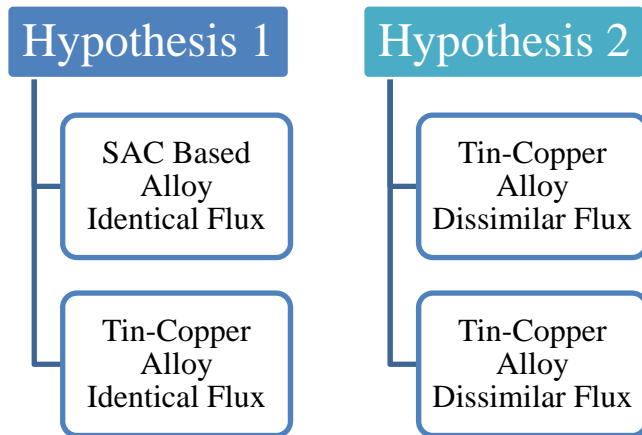
**Figure 1.** Use of Cored Solder Wire in Edison Socket Based Retrofit LED Bulb

The ability to quantify the reflectivity of solder joints allows designers and manufacturers to have the capability to quantitatively assess (I) aesthetics of the solder joints, and (II) impact of flux residue.

- I. Aesthetics plays a unique role in LED assemblies this is due to solder joints being physically exposed to consumers in a variety of lamps/luminaires that incorporate Edison based caps as shown in Figure 1. In general, manufactures and assemblers will clean the end caps to ensure an aesthetically pleasing solder joint.
- II. Typically, LED manufacturers use reflective white solder masks to maintain the brightness levels of the luminaire. Increased levels of flux residue browning on a white solder mask can absorb light, thus affecting the brightness of the luminaire.

Accordingly, this study proposes to validate the technique developed by Alpha by means of measuring the reflectivity under two independent evaluations as depicted in Figure 2. (Evaluation-I) cored wires with two different alloys that use identical flux chemistries and (Evaluation -II) cored wires that use Tin-Copper alloys with dissimilar flux chemistries

tested against a known calibrated mirror. The methodology of quantifying reflectivity and experiment results are discussed in this paper.



**Figure 2.** Hypothesis Test Set Up

The motivation for running two different evaluations is to ultimately test the sensitivity of Alpha’s technique to quantify reflectivity. The first phase (Evaluation-1) asks the question if the technique of quantifying reflectivity is capable of discerning between two alloys which are fundamentally dissimilar in visual appearance. [1] The second evaluation attempts to quantify the difference between two of the same family of alloys with dissimilar rosin-based flux chemistries, ultimately measuring the influence of flux on the reflectivity of the alloy.

**ASSEMBLY MATERIALS & EQUIPMENT**

**Cored Solder Wire**

The alloys evaluated in this study are tin-copper and SAC (tin-silver-copper) based alloys. The alloys are in the form of a cored solder wire with a continuous core of 2% rosin flux.

**High Precision Solder Feeder**

In order to compare different flux chemistries and different alloys of cored solder wires it is crucial to reduce as much variable noise from the assembly as possible. An automated high precision solder wire feeder is used to reduce the variation. The solder wire feeder allows (I) the precise amount of solder wire weight to be deposited onto the test cap coupon and (II) ensures the rate of solder deposited is consistent throughout the entire assembly removing the need to manually assemble the caps.

**Substrate / Coupon Cap**

A brass cap component treated with the process of electroplated nickel is used as shown in Figure 3. A key factor in testing the reflectivity of the proposed solder alloys is to have a consistent surface structure. A variety of different coupons / substrates were tested to generate the most consistent and even solder surface morphology. Once assembled, the cap structure used in this study produced, along with other factors explained in the other sections of

this paper, the lowest variation in the morphology of the solder structure.



**Figure 3.** Solder Cap Fixture

**Soldering Station**

A digital soldering station with an adjustable solder tip temperature was used to conduct assemblies at various solder iron tip temperatures.

**Spectrometer, Light Source and Probe**

The human eye perceives specular reflection as a continuum from dull to shiny. This is a subjective, qualitative measurement. However, an optical reflectance meter measures spectral reflectance via the ratio of incident to reflected light from a surface. In this way spectral reflectance can be measured more accurately and quantitatively than by a human.

The experimental apparatus consists of a commercially available tungsten-halogen lamp connected via fiber optic to a reflectance probe and a spectrometer with a wavelength range of 350-1000 nm.[2] The probe is a 6-around-1 bifurcated fiber bundle with six incident fibers and one return fiber. A neutral density filter is used to reduce the light intensity in order to match the dynamic range of the detector.

**Calibration**

Initial calibration is performed against a NIST-traceable aluminum-on-fused silica mirror. In this way the reflectance measurements of various samples are compared to a common, known standard. The reflectivity of the mirror used in this study was ~87 – 93% in the visual range.

**PROCESS AND TEST METHOD**

**Sample Processing**

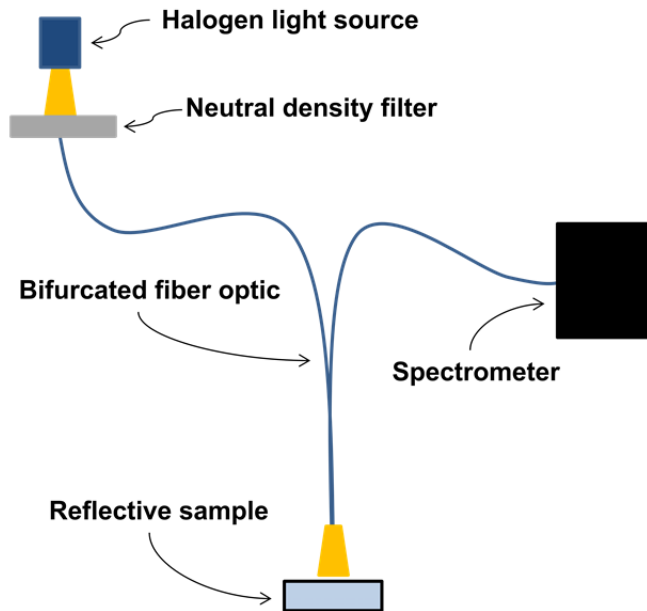
Reducing the variability of the assembly process is crucial. There are important factors which need to be controlled when attempting to form a consistently even solder surface. This is important because the reflection analyzing system is sensitive to surface morphology. [3] The largest sources of noise when soldering the test cap coupons are: (I) the rate at

which the solder is reflowed onto the substrate, (II) the weight of solder and (III) the temperature of the solder iron. These noise factors were controlled in the following manner: (I-II) a high precision automatic solder-wire feeder enabled the precise amount of 0.5grams of solder wire length to be fed onto the end cap at a rate of 10mm/s. A total of 15 caps were soldered for each alloy to produce a good statistical sample size.

(III) The assembly of the samples used a digital soldering station with an adjustable dial to vary the solder iron tip temperature. The solder iron tip was validated during the assembly of each cored wire assembly. The end caps were assembled at three tip temperatures: 650,750 and 800C.

**Test Method**

A custom built fixture is designed to ensure (I) repeatability of the assembled coupon caps against the reflection probe and (II) further minimize the ambient light entering the probe during testing. The soldered samples are placed at a fixed distance from the probe to emit a beam of light that covers no more than the solder surface of 10mm in diameter. The halogen light source transmitted through a neutral density filter emits light on to the soldered end cap via a bifurcated fiber optic probe which serves as both a transmitter and receiver. The receiving end of the probe collects the amount of visible light reflected back and is analyzed through the spectrometer’s software which ultimately provides a reflective percentage calibrated against a mirror. Figure 4 depicts the test setup of measuring the reflective percentage of the soldered samples.

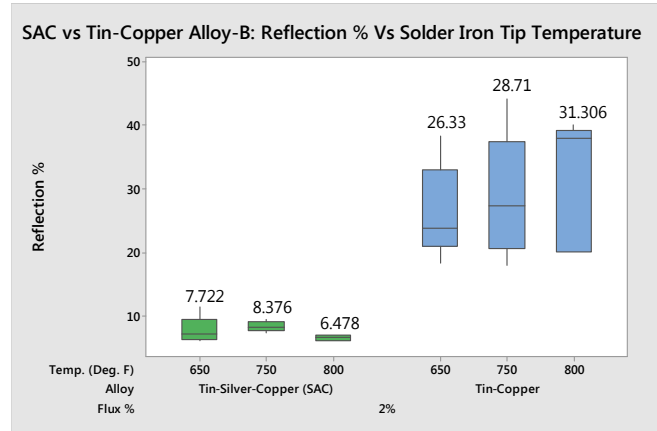


**Figure 4.** Reflection Test Set Up

**RESULTS AND CONCLUSIONS**

**Results of Evaluation I**

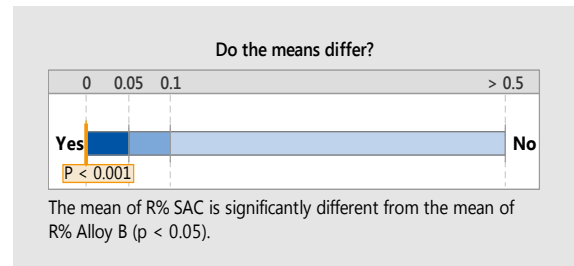
When two different alloys are used the system is able to discern differences in reflectivity between them. The tin-copper alloy produces higher reflectivity at each tip temperature than the SAC305 alloy as shown in Figure 5A and supported by the P-Value in Figure 5B.



**Figure 5A.** Tin-Copper vs SAC305 Reflectivity

**Table 1.** Results of Reflection Value Based Off Solder Iron Tip Temperature for Dissimilar Alloys

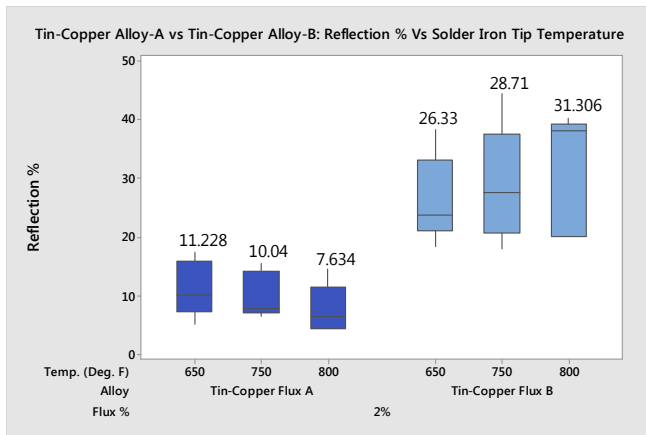
Solder Iron Tip Temperature	SAC Alloy Identical Flux	Tin-Copper Identical Flux
650F	7.72	26.33
750F	8.37	28.71
800F	6.47	31.30



**Figure 5B.** Statistical Difference of Reflection Values for Dissimilar Alloys

**Results of Evaluation II**

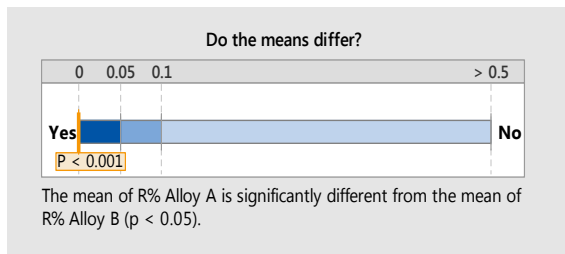
When analyzing Tin-copper alloys with dissimilar flux chemistries and varying solder iron tip temperatures the results indicate that a significant difference exists in the reflectivity as shown in Figure 6A further confirmed by the P value in Figure 6B.



**Figure 6A.** Tin-Copper Alloys with Dissimilar Flux Chemistries Reflective Values

**Table 2.** Results of Reflection Value Based Off Solder Iron Tip Temperature for Dissimilar Flux Chemistries

Solder Iron Tip Temperature	Tin-Copper Dissimilar Flux A	Tin-Copper Dissimilar Flux B
650F	11.22	26.33
750F	10.04	28.71
800F	7.63	31.30



**Figure 6B.** Statistical Difference of Reflection Values for Dissimilar Flux Chemistries

## CONCLUSIONS AND SUMMARY

Reflective values of assembled solder joints are seldom if at all analyzed in the market place. However, in new applications such as LED lighting, the ability to precisely quantify the reflectivity of alloys can provide important added value and implications.

The technique of using a spectrometer system to scatter visible light onto a soldered sample and measure its reflective value against a standard mirror enables objective comparison between different solder alloys and flux chemistries far better than human perception.

In conclusion, based on the results of measuring both dissimilar alloys and flux chemistries the techniques of measuring solder joint reflectivity demonstrate that the influence of the assembly processes and choice of materials can affect the reflective values of a final solder joint assembly.

## REFERENCES

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