Non-Destructive Real-time Optical Metrology of OSP Coatings on Production PCBs

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Introduction

Organic Solderability Preservative (OSP) coatings feature among the leading surface finish options in the printed circuit board (PCB) industry because of their excellent solderability, lead-free applicability, ease of processing, and low cost. OSP coatings are primarily composed of organometallic polymer with small molecules such as fatty acids and azoles entrained during the coating deposition process. OSP coatings are deposited on the Cu features of PCBs. They are transparent across the visible spectrum and they typically range in thickness from about 0.1µm – 0.6µm.

UV-Visible absorption characterization is the most frequently used technique to estimate OSP coating thickness. This method requires that a control sample be sent through the OSP line and coated with OSP. This OSP layer is then removed from the control sample using organic solvents, the solution is analyzed, and the thickness of the original coating is inferred. The OSP thickness on the active PCB is assumed to be equivalent to that of the control sample. The method is indirect, destructive, requires control samples, and does not yield any information concerning the uniformity of the coating. Furthermore, the wet-phase preparation steps make this technique susceptible to large experimental errors.

In this contribution the use of Optical Reflectivity for direct OSP metrology will be explored. Optical Reflectivity measurements are completely non-destructive, differentiating them from other technologies used to measure OSP thickness. Typically, the small probe area ensures that individual PCB features or regions of interest can be chosen for analysis. The non-destructive nature of the measurement ensures that quantitative data from OSP coatings can be collected at any time during the PCBs lifecycle. Adverse effects due to production steps and ageing on the OSP film can readily be measured. Control samples and test coupons become redundant and the circuit board itself does not require any sample preparation following OSP deposition.

Measurement Principle

In order to perform Optical Reflectivity on PCBs we have developed a specialized instrument (Figure 1) that measures thin-film characteristics by analysis of spectral interference. It functions by reflecting light over a range of optical wavelengths (400nm-700nm) from layered samples. Light reflected from the Air/OSP interface and the OSP/Cu interface exhibits phase differences that create intensity oscillations across the wavelength range. By analyzing the frequency and amplitude of these intensity oscillations one can determine the thickness of the OSP coating in much the same way that a conventional ellipsometer evaluates film thicknesses.

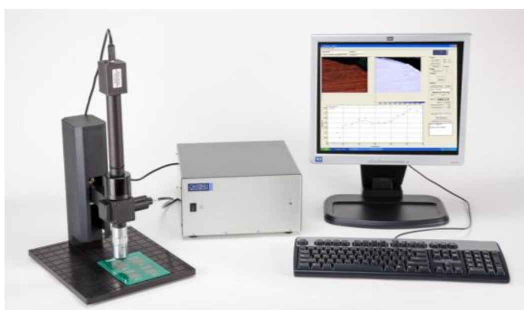


Figure 1. The OSPrey800 is a specialized instrument for performing film thickness measurements of OSP on PCBs.

OSP coatings of thickness 0.02µm - 5µm can be determined using fundamental parameter analysis without the need for calibration standards. The benefits offered by optical reflectivity are that OSP thickness can be measured directly in-situ on production circuit boards. Control samples are no longer required.

Experimental Section

A series of OSP coated Cu coupons were measured using Optical Reflectivity. The aim was to measure the average coating thickness and compare this thickness with the value predicted using the UV-Visible technique. It can be seen from Figure 2 that a perfectly linear relationship exists between the thickness determined by the UV-Visible method and the thickness measured using Optical Reflectivity.

OSP coatings can be directly viewed using electron microscopy. A cross sectional image of an OSP coated Cu system is presented in Figure 3. The width of this image corresponds to about 4 µm. A Platinum (Pt) layer was evaporated on top of the OSP to enhance the contrast in the electron microscope. Comparisons between the thicknesses measured using Optical Reflectivity and that measured using the FIB/SEM can be seen to the right of Figure 3. It can be seen that the results are in good agreement, within a few percentage difference in most cases. It should be noted that the SEM method estimates coating thickness using a cross-section a few µm wide while the reflectivity measurement averages over a surface area of thousands of μm^2.

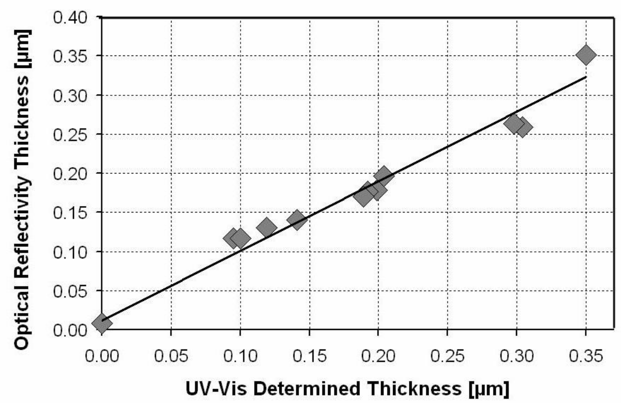
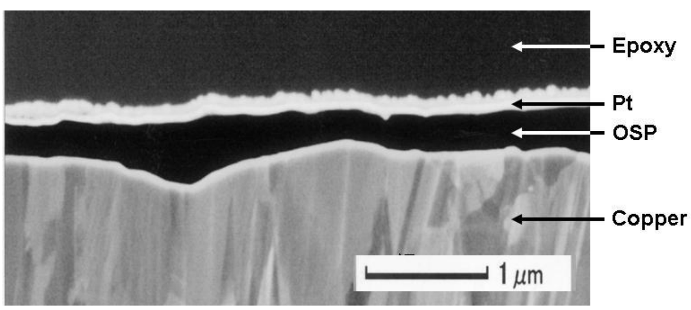


Figure 2. Plot of OSP coating thickness as determined by the UV-Visible method against the thickness measured by Optical Reflectivity.



Optical Ref. [µm]	FIB/SEM [µm]
0.156	0.164
0.148	0.149
0.109	0.107
0.158	0.112
0.145	0.154
0.144	0.137
0.159	0.153

Figure 3. Cross sectional SEM image of an OSP coated Cu system and comparisons of Optical Reflectivity measured thickness with the thickness determined using the FIB/SEM technique.

Optical Reflectivity can be combined with a detector array to produce thickness maps of the OSP coating in 2 dimensions. An example of such a thickness map is presented in Figure 4. In this image the coating thickness is represented on a white to blue color scale. The thicker regions of the coatings are bluer in color while the whiter areas represent thinner coated OSP regions. OSP tends to fill in the ‘valleys’ and sit thin on the ‘peaks’ where the ‘valleys’ and ‘peaks’ refer to the geometric minima and maxima of the Cu surface roughness profile.

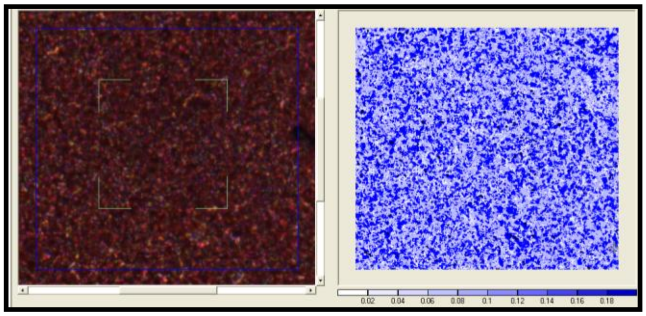


Figure 4. To the left hand side is a digitally zoomed image of the OSP coated Cu surface. The profile of the OSP coating thickness corresponding to the left hand image is depicted on the right hand side. This right hand image is a thickness map of the coating. On the thickness map the areas of thinner OSP coating appear 'whiter' while the areas of thicker OSP coverage appear 'bluer', and a colour scale appears beneath the image. The mean thickness of this OSP coating was measured as 0.15µm by averaging the components of the thickness map.

Conclusion

Optical Reflectivity is capable of providing repeatable and accurate measurements of the thickness and integrity of OSP coatings on production PCBs. These measurements do not have any adverse effects on either the PCB or the OSP coating. The technique is remarkably precise and exhibits a perfectly linear relationship with data generated using the currently accepted UV-Visible method on Cu test coupons. The magnitude of the average coating thickness measured by Optical Reflectivity is also in good agreement with coating thicknesses determined using a FIB/SEM procedure. Optical Reflectivity provides a real-time solution to non-destructively measure the thickness and quality of OSP coatings on PCBs. We have developed a customized instrument to measure OSP on PCBs called the OSPrey800 to implement this solution.

Acknowledgement

Oxford Instruments would like to sincerely thank Shikoku Chemical, Japan, for contributing to useful discussions and for providing OSP coated Cu samples to facilitate this study.