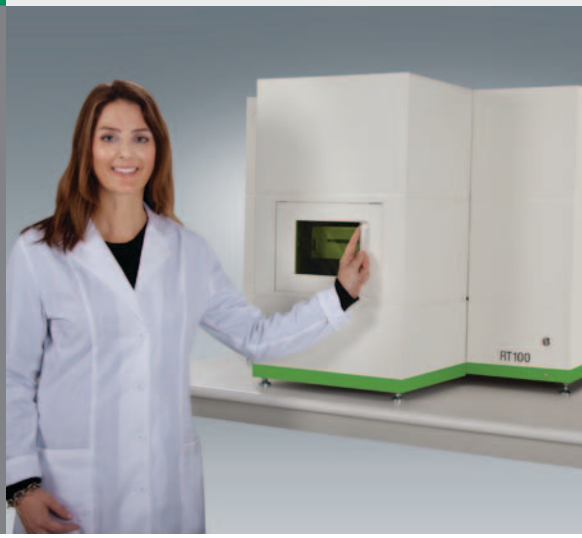
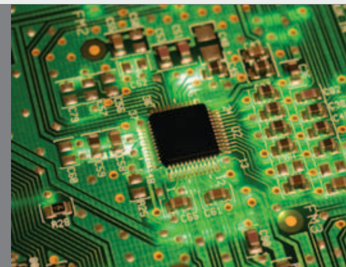
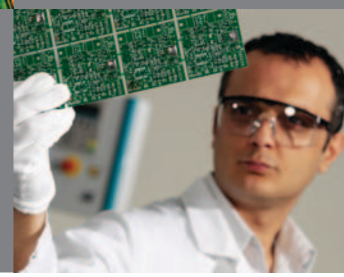
Rapid Lead (Pb) Analysis of Solder Plating on Semiconductor Leadframes







Application Note

The RT100 series LIBS system outperforms five other methods for Pb detection

Summary

The presence of lead (Pb) in human blood has been linked to severe neurological, behavioral and developmental problems, especially in young children. As a result, the European Union passed the Restriction of Hazardous Substances Directive (RoHS) which bans the use of Pb, as well as Cd, Hg, Cr (VI), polybrominated biphenyl (PBBs) and polybrominated diphenyl ethers (PBDEs) above a specified concentration in electronic products.

The Quality Control Department at Spansion, Inc (Malaysia), a major manufacturer of memory chips, worked together with Applied Spectra's scientific team. Using Applied Spectra's RT100 series LIBS (Laser-Induced Breakdown Spectroscopy) system, they were able to rapidly determine the concentration of Pb in the solder plating of semiconductor leadframe packages, and they did so without the need for sample preparation. Figure 1 illustrates the physical process that leads to optical emission during a LIBS measurement.

The RoHS directives establish a maximum allowable concentration limit of Pb at 1000 ppm for electronic devices and equipment. With manufacturers worldwide adopting the RoHS directives, it is essential for semiconductor suppliers, such as Spansion, to verify their RoHS compliance. The RT100 series LIBS system proved to be a rapid and accurate tool for the determination of Pb concentration levels in the solder plating finish of Spansion's semiconductor leadframe packages.

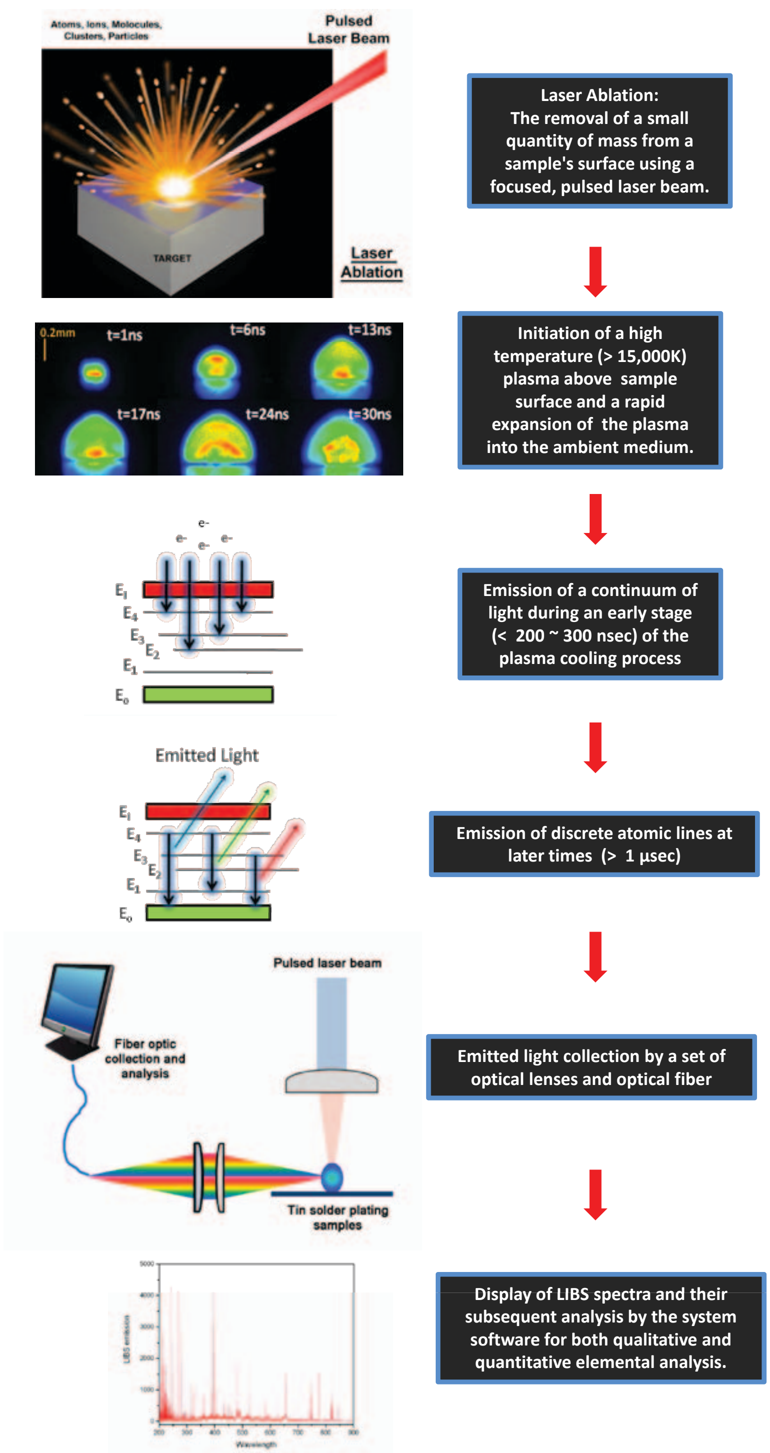
Current Conventional Techniques

Currently, Inductively Coupled Plasma-Optical and Atomic Emission Spectroscopy (ICP-OES and ICP-AES) are used in industry as analytical methods for RoHS compliance verification.

However, ICP-OES requires complex and time-consuming acid dissolution of solid samples prior to analysis, as well as significant scientific expertise to perform the analysis. This makes ICP-OES unfit as a rapid Pb monitoring technique for applications requiring high throughput of samples for quality control.

XRF-based techniques have been used in recent years for monitoring Pb in finished products. Although convenient, XRF techniques face challenges in providing accurate and precise concentration determination for thin and small samples, such as those found in tin solder plating for leadframe packages. Consequently, industry generally uses of XRF for screening of RoHS elements, rather than for final determination of the elemental content.

Figure 1. Physical processes leading to plasma emission during LIBS measurement.



The RT100 LIBS system was evaluated against five different methodologies to measure Pb concentrations in solder plating, including the following elemental analysis techniques:

- ICP-OES,
- Atomic Absorption (AA),
- Energy Dispersive X-ray Fluorescence (EDXRF),
- micro-EDXRF, and
- Laser Ablation–Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS).

Operating Parameters

- Sample: Tin-plated semiconductor leadframe packages
- Laser spot size: 120 microns
- Laser Wavelength: 1064 nm
- Laser power: 50 mJ

Sample Preparation and Analysis

The samples used in this study were pure tin-plated, "thin small-outline package" (TSOP56) products. These samples were divided into two groups: 1) tin plated TSOP56 packages at three different current densities, and 2) a group of 28 leadframe packages produced without tin plating deposited on the leads, leaving the original bare copper substrate exposed. The last group acted as a control lot. Table 1 summarizes different currents applied to produce tin plating with three Pb concentrations.

The samples were submitted to external, third-party laboratories for ICP-OES, AA, EDXRF, micro-EDXRF, and LA-ICP-MS analysis. LIBS analysis was performed at Applied Spectra's research and development laboratory in Fremont, CA using the RT100-HP system (Figure 2). Laser and spectrometer parameters of the RT100 were optimized for the detection of Pb.

Table 1. Summary of TSOP56 packages prepared with three different levels of Pb content of Sn plating.

No	Pb Level	Plating Current	Total Quantity
1	Low	Tin Plating at 50ASF	28 Strips
2	Regular	Tin Plating at 140ASF	28 Strips
3	High	Tin Plating at 200ASF	28 Strips
4	Copper bare frame	No Tin Plating	28 Strips

Standards were obtained from NIST and MBH Analytical Ltd and contained Pb concentrations of 36 ppm, 146 ppm, 403 ppm, and 960 ppm. These standards were used to generate calibration curves for quantification of Pb using the RT100. Figure 3 shows typical LIBS spectra of a standard reference materials (SRM) containing 403 ppm of Pb. The laser spot size was 120 μm at 10 mJ of laser energy using the RT100 LIBS system. A calibration curve was generated by recording the LIBS intensity for Pb emission at 405.7 nm for four different SRMs with known Pb concentrations (Figure 4).

LIBS analysis was performed by laser ablation of the bottom of individual leads on the sample. The bottom side of the leadframe package comes into physical contact with punching dies during the end-of-line processes. Since electronic test equipment usually handles products with and without Pb content, cross-contamination may occur during contact between sockets and package external leads. Optical microscopic images before and after laser ablation are shown in Figure 5(a) and 5(b). The scanning electron microscope (SEM) image of the ablated site on the lead shows additional morphological details of the laser ablation sampling area (Figure 6).

Figure 2. The RT100 series LIBS system

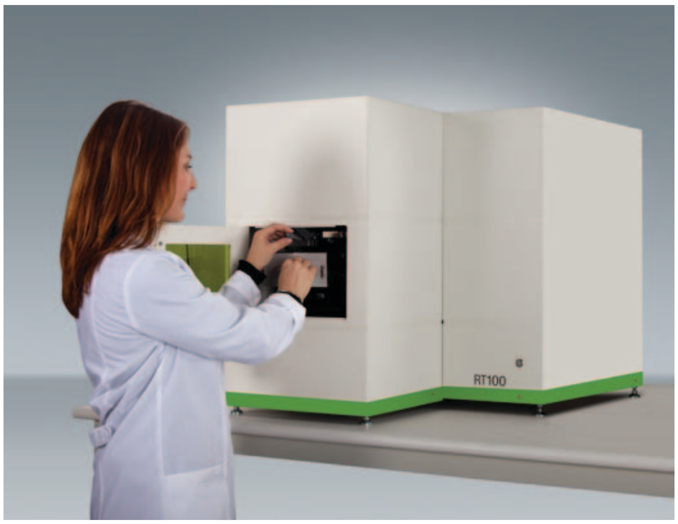


Figure 4. Representative LIBS calibration curve for quantitative lead analysis

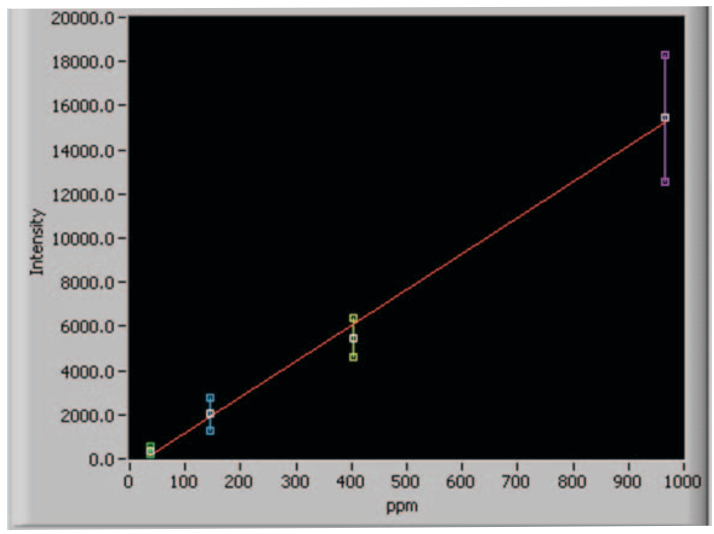
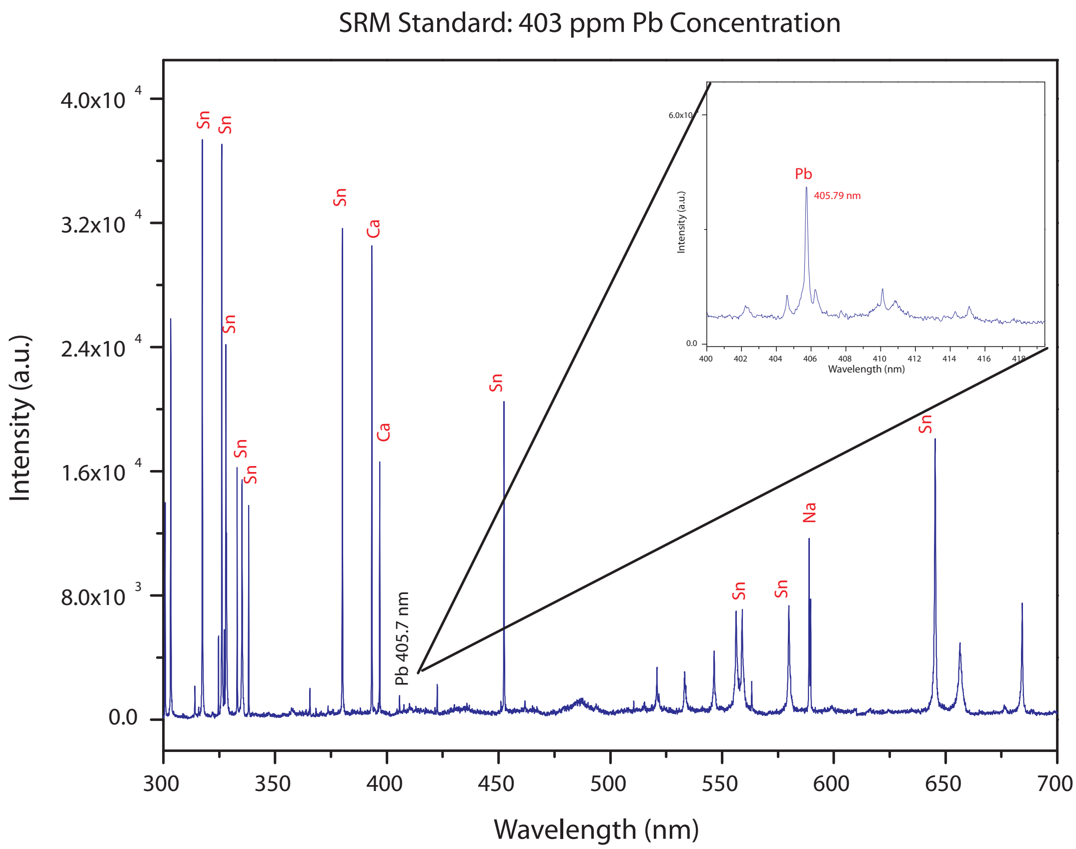


Figure 3. Typical LIBS spectrum of standard reference material (SRM) containing 403ppm of Pb.



Results

Six analytical techniques were used to determine the concentration of Pb in the tin plating of TSOP56 packages. Three different current densities were used to deposit tin plating on TSOP56 packages with results shown in Table 2. As the plating current density increases, the expected value for the Pb content should also increase. The micro-EDX and EDXRF techniques were not able to detect Pb (BL= below detection limit) at any of the three current settings. The XRF instruments used for this study at the independent testing laboratories did not have sufficient detection sensitivity.

LIBS, LA-ICPMS and ICP-OES showed very similar results on most samples except that ICP-OES could not detect lead (ND= not detected) for the lowest plating current (50ASF) used. Table 2 also shows that Pb content was similar for tin plating produced at medium- and high-current density, while it was lower for tin plating produced at the lowest current setting. AAS showed a consistently lower Pb concentration at all plating currents. However, AAS detected about 12 ppm of Pb in bare Cu substrates while other techniques did not detect the presence of Pb. This difference may have been due to potential contamination of samples or prepared solutions.

Figure 5 (a). Bottom side of the plated lead before laser ablation,
Figure 5 (b). Bottom side of the plated lead after laser ablation.

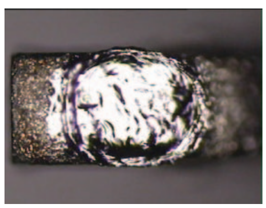


Figure 6. SEM image of the ablated sample area on the lead.

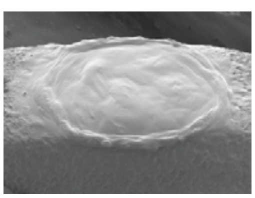


Figure 7 shows the summary of Pb concentration results from AAS, ICP-OES, LA-ICP-MS and LIBS. The results show close agreement of Pb concentration values among LIBS, LA-ICP-MS and ICP-OES.

Conclusions

LIBS proved to be a rapid, accurate, and cost effective approach for monitoring Pb in tin plating products.

XRF-based techniques did not provide sufficient detection limits and the precision performance necessary to accurately determine and monitor the Pb content of leadframe package products. AAS and ICP-OES are traditional techniques within the electronics industry, but due to extensive sample preparation time, they are unfit for fast, on-line monitoring.

LIBS analysis for Pb in leadframes produces results that correlate with data obtained from ICP-OES. In addition, LIBS provides fast measurement times, together with the ability to monitor Pb content at various leadframe manufacturing steps. Since LIBS requires no sample preparation, it is a well-suited elemental technique for RoHS compliance testing. LIBS also eliminates toxic chemical waste disposal issues, thus reducing the cost-of-ownership and improving worker safety. LIBS is an environmentally friendly alternative to traditional methods of Pb analysis.

Figure 7. Pb concentration comparison between AAS, ICP-OES, LA-ICP-MS, and LIBS for Sn plated TSOP5656 leadframe packages at different current settings.

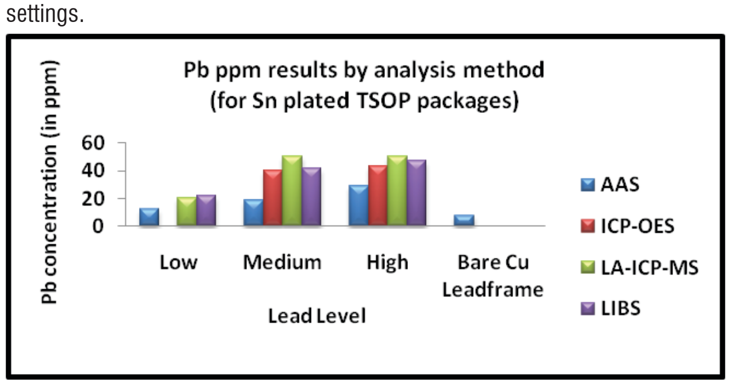


Table 2. Comparison of Pb concentration (in ppm) determined by different analytical techniques for Sn plating of TSOP5656 leadframe packages deposited at three different current settings.

No	Lead Level	Plating Current	PPM Level by Analysis Method					
			AAS	ICP-OES	Micro-EDXRF	EDXRF (5mm)	LA-ICP-MS	LIBS
1	Low	Tin plating at 50ASF	12.2	ND	ND	BL	20	22
2	Regular	Tin plating at 140ASF	18.7	40	ND	BL	50	42
3	High	Tin plating at 200ASF	29.3	43	ND	BL	50	47
4	Copper bare frame (control lot)	No tin plating	7.4	ND	ND	BL	ND	ND
Legend: ND - Not Detected, BL - Below Detection Limits								

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