Handheld XRF for Coating Thickness and Coating Composition Measurement

Bogert, James R., Matrix Metrologies, Inc., Holbrook, NY USA

X-Ray Fluorescence (XRF) spectrometry is a widely accepted technique for nondestructively measuring the thickness and composition of coatings. To-date, spectrometer designs for these applications have been bench-top systems using beam collimation to measure small parts and / or features. When the product or material is too large to fit in the chamber it has to be cut or dismantled, thereby eliminating the non-destructive benefit of the technique. Handheld XRF units enable the non-destructive analysis of large product, and in many cases small parts as well with the use of a unique analysis approach to deal with small samples being of less than infinite area to the larger beam size of the handheld unit. Additionally, due to the portability of handheld XRF the user can take the lab to the process and make measurements in real time at the plating bath.

This paper will compare the accuracy and precision of coating measurements made with Handheld XRF to those made with a conventional Bench-top system. We will also discuss criteria for choosing the appropriate XRF tool for the application - handheld or bench-top.

For more information contact: James R. Bogert Matrix Metrologies, Inc. P.O. Box 962 El Granada, CA 94018 USA Phone - +1 650-560-9029 E-mail – jbogert@matrixmetrologies.com

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Over the past couple of decades X-ray Fluorescence (XRF) spectrometry has become a standard method for measuring thickness and composition of single and multi-layer coatings for metal finishers. Attractive qualities of XRF to the metal finishing industry are that it is non-contact, non-destructive and rapid, and can be easily automated.

One of the most significant innovations in XRF in recent years has been the packaging of a very capable spectrometer in a truly portable, handheld package. Two markets have driven this development – environmental (Pb in paint, Pb and other heavy metals in soil) and alloy identification, verification and sorting (scrap metal dealers and metal fabrication). The primary requirement of these markets that the handheld configuration has met is the ability to take the laboratory to the sample whether it is in an old house, industrial waste site or scrap yard. In each case sampling can be very labor intensive and there are distinct advantages to being able to provide rapid, essentially immediate results from which a business decision can be made. This may be sampling locations and the extent of sampling in the case of environmental applications; the value of a load of scrap coming into a yard, or the acceptance or rejection of fabricated reactor at a petrochemical plant (are the materials those that were specified?). So, what does a portable handheld XRF tool afford the plating and surface finishing industry? One benefit has been introduced – the ability to take the laboratory to the sample or process. Another major benefit lies in the fact that the handheld is out of the box, thereby, extending the non destructive nature of X-ray fluorescence to large pieces that cannot fit into a bench-top analysis chamber and would otherwise need to be cut for analysis.

This paper presents the hardware and software features required of handheld design; how they compare to a standard bench-top design; the benefits and tradeoffs and application performance. As noted above, handheld XRF is widely accepted for measuring alloy, base metal composition. We will focus on the measurement of coating thickness and composition with handheld XRF.

XRF Spectrometry as applied to Thickness & Composition Measurement:

X-ray Fluorescence is an atomic spectroscopy technique where an ionizing source (typically from an X-ray tube) is shined on a material. The ionized atoms of the material transition between the ionized state and ground state while being bombarded by the source X-rays. These transitions emit X-rays (fluoresce X-rays) that are characteristic of the atom or atoms that make up the material. They are characteristic in that the energies of the fluoresced photons are proportional to

the atomic number of the atom and provide qualitative information. For a set instrument condition, the frequency of a specific emission is proportional to the amount of the atom present in the material. The fluoresced photons are counted by a detector, usually a gas-filled proportional or Si based solid-state detector. The technique counts the variety and number of atoms over the area irradiated by the source providing mass per unit area (mass thickness) quantification and composition. If the density of the material is known or can be calculated based on the relative amounts of each element, mass thickness can be converted to linear thickness by dividing by the density. The conditioned termed infinite thickness is when the thickness of the material is such that highest energy photons fluoresced in the material are reabsorbed by the material. Infinite thickness is a function of the energy of the fluoresced photons and the composition of the material and so will vary accordingly. When the infinite thickness condition applies to all the analyte emissions of the material being irradiated then only material composition can be determined, i.e. base alloy composition. The practical thickness measurement range for most commercial spectrometers is ~ 50 Å (0.2 µin) to ~100µm (4,000 µin).

In multi-layered systems it is necessary to define the order in which the layers are deposited, i.e. Au on Ni on Cu base. The absorption effect alluded to in the previous paragraph impacts thickness measurement of multi-layers from both, an individual composition and thickness, as well as, layer position perspective.

So, for accurate analysis absorption must be taken into account. In a single element layer this is simply self absorption. In multi-element and /or multi-layer analysis this includes inter-element and intra-layer absorption and where there is absorption there is potential for emission enhancement. Inter-elemental enhancement is when a fluoresced photon has the potential to excite other atoms within the material or between layers. These absorption and enhancement effects are often referred to as matrix effects.

Correcting for these effects, particularly in a complex multi-element, multilayered system becomes very calculation intensive, and so, it has only been over the past two decades with development of fast, low cost computers that XRF has been routinely applied to coating thickness and composition measurement. Of course, this also requires software algorithms that can accurately characterize these effects. The trend in XRF has been the use of more theoretical algorithms using X-ray physical parameters, referred to as Fundamental Parameters (FP) that have replaced more empirical algorithms, which require numerous and often costly standards and labor intensive calibrations to characterize the matrix effects. Thickness measurements presented in this paper were derived from FP algorithms.

Handheld XRF and Bench-top XRF Components:

Most XRF systems used for thickness and composition measurement have been either of floor-standing or bench-top design. In this section we compare the functional design features of a conventional bench-top system and a handheld, and what this means to coating thickness and composition applications. Of course, the essential requirement for a portable instrument is that it be easily carried requiring reduction in size and weight, which impacts the design of all the spectrometer components. The most challenging component miniaturizations for XRF have been the X-ray source, detector, and computing platform. Photos of the instrument types compared in this paper are presented in Figure 1.

Figure 1



Figure 1: Bench-top (left) – exterior dimensions: 18" H x 16" W x 26" D, 100 lbs., and Handheld XRF (right) – 12" L x 9" H x 3" W, 2.6 lbs. instruments discussed in this paper.

X-ray source: A tube based source is the preferred source because it can be easily controlled unlike, radioisotopes that emit at specific energies and cannot be turned off. Most bench-top instruments use 50 kV, 1.0 mA tubes – 50 W maximum output. To be portable, re weight and power draw (battery operation) requirements, handheld XRF tubes are much smaller and are typically powered at 40 kV and 10 μ A – 4 W maximum output. The lower operating power of the mini X-ray tube used in the handheld configuration, which yields lower incident flux, is compensated for by using a less collimated beam and a tight working distance (tube-to-sample and sample-to-detector distances). The less collimated beam results in a greater irradiated area, the tight geometry provides higher photon density over that area. In normal use the handheld "probe" is flush with the analysis surface. This geometry irradiates an area of ~7 mm diameter, 38 mm². Whereas, most bench-top designs for coating thickness can be and are usually highly collimated in order to enable the analysis of small parts or focus in on specific sample areas and features. Also, layer analysis has historically required that the sample be of infinite area to the incident beam (larger than the

beam area and contiguous). This is because either the fluorescence from the coating or in an inverse relation the absorption from the substrate is used to determine coating thickness. A lesser coating intensity due a small sample (smaller than the irradiated area) will naturally be interpreted as a thinner coat than it is, and if substrate absorption is used, the lesser intensity from a substrate signal will be interpreted as a thicker coat than it is. So, sample size can be what might seem a limiting application factor. However, with certain layered systems this can be overcome, if both layer emission(s) and absorption of the substrate emission by the layer(s) are used simultaneously. Measurement may still be limited by beam size for the condition that must be met is that analyte emissions detected (layers and substrate) must be representative of a defined film structure and have an infinitely thick substrate. However, this approach can greatly increases the applications that may be addressed with a handheld XRF system. This will be discussed in more detail later in the paper.

<u>X-ray detector</u>: The most common detectors used for XRF thickness and composition instruments are gas-filled proportional counters, which have been the standard for bench-top configurations, and newer Si-PIN detectors. Both detector types are now offered in bench-top configurations. As with X-ray tubes, portability requires a small, light detector, which the Si-PIN detectors provide. And although, they require cooling to reduce thermal noise, this is achieved with power economy via a Peltier device. The smallness of the Si-PIN also sacrifices the active area capable of capturing fluoresced X-rays. However, as with the tube this is compensated for by close coupling of the detector to the sample.

The distinct advantage of the Si-PIN over the gas-filled proportional counter for X-ray spectrometry, and why they are implemented in "higher-end" bench-top systems, is their energy resolving power, which is typically 5 times better than a proportional counter. The improved resolution eliminates many peak overlaps completely, which are potential sources of error, and enables qualitative identification and rapid quantification of even very similar alloys. Additionally, Si-PIN detectors exhibit better peak-to-background (single-to-noise) response than proportional counters, which results in improved detection limits in terms of both concentration and coating thickness. Peak resolution (peak width) and peak-to-background response are graphically depicted in the comparative copper spectra of a gas-filled proportional counter to Si-PIN in Figure 2.





Figure 1: Copper spectra acquired with a gas-filled proportional counter (red spectrum) and a Si-PIN detector (black line spectrum) are compared. A typical Si-PIN employed for XRF has a peak width of 220 eV Full-Width-Half-Max (FWHM) at 5.90 keV and a gas-proportional counter typically exhibits resolution of 900 – 1000 eV FWHM. So, where the Si-PIN completely resolves Cu K α and Cu K β emissions the Cu K β is a high energy tail in the proportional counter spectrum. The spectra presented are count normalized to the mauve area to demonstrate the peak-tobackground improvement (~2.5X) of the Si-PIN to the gas-filled proportional counter for the same integral intensity.

<u>Instrument Control and Data Processing</u>: The trend, as with the computational industry in general, has been miniaturization – minicomputers, then personal computers, and now laptops have become popular instrument control and data processing platforms for bench-tops, but handheld implementation demands an even smaller and lighter platform – the pocket PC. Pocket PCs provide a convenient tapping interface and can now process the process intensive X-ray Fundamental Parameters algorithms in a very functional time frame of ~3 seconds for a single layer coating and 8 seconds for a dual layer coating.

Analytical Performance:

To compare analytical performance of handheld XRF to bench-top XRF for thickness measurement, a simple single layer application was selected, Zn plating on carbon steel. A series of standards ranging in Zn thickness from 2.63 - 25.60 μ m (105 – 1024 μ in) were measured to demonstrate analytical precision and accuracy in a very practical analysis time of 10 seconds or less real time. The

standards are certified by the vendor to be accurate to $\pm 5\%$ relative. The standards are of infinite area to the handheld beam having dimensions of 2 cm x 2 cm to 3 cm x 3 cm.

Numerous factors (sources of error) can contribute to analytical instrument precision and accuracy. In XRF the primary contributor to analytical precision over which the user can exert control is counting statistics, which deviate (standard deviation) as the square root of the accumulated analyte photon count. So, given a stable instrument, the longer you count the better analytical precision. In order to compare instrument precision acquisition times were selected to provide comparable accumulated counts. The basic instrument configurations, excitation conditions, count acquisition times and predicted precision are presented in Table 1.

Parameter	Handheld	Bench-top
Tube potential (kV)	35	40
Tube current (µA)	4	100
Beam diameter at the sample (mm)	7	0.3
Detector	Si-PIN	Prop Counter
Approximate analyte count rate from 7.70 μm thick Zn plating (counts per second)	1200	2800
Acquisition live time (sec.)	7.4	5.0
Predicted 2 σ Relative Precision (%)	2.1	1.7

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Table 1: Count acquisition times were set to provide similar statistics and therefore, similar precision for real-time acquisitions of < 10 seconds and precision of $\sim 3\%$ relative or better at 95.4% confidence.

Most analytical instruments are comparative techniques that must be calibrated to standards, and therefore, analytical accuracy is largely dependent upon standards quality. XRF is somewhat unique in this regard in that Fundamental Parameter (FP) algorithms under certain conditions can eliminate the need for calibration to standards. In almost all cases FP eliminates the need for "type" standards. Type in this sense means standards that are similar in composition and / or thin-film structure to the materials that are to be measured. For the analyses presented here, pure bulk (infinitely thick) metals were used as sensitivity references in conjunction with FP algorithms to calculate thickness from fluoresced Zn and Fe intensities. Analytical algorithms are the other parameters greatly impacting

analytical accuracy. Although, both instruments utilize FP programs, the programs are not identical.

Eight standard Zn plated iron standards were analyzed per the instrument parameters described above. Zn thicknesses were as follows:

Standard ID	Zn Layer Thickness
G582	$2.63~\mu m$ / 105 μin
G434	$5.10~\mu m$ / 204 μin
G581	7.70 μm / 308 μin
E105	6.68 μm / 267 μin
E107	9.63 µm / 385 µin
E117	14.18 μm / 567 μin
E118	$20.50~\mu m$ / $820~\mu in$
E120	25.60 μm / 1024 μin

To compare the analytical precision of the two instruments for the Zn plated steel application, standards G582, G581 and E118 were analyzed 20 times each. Analysis results are presented in Tables 2, 3 and 4 respectively. Measurement precision for each set of analyses is generally within that predicted by counting statistics. Accuracy, to the given standard values, which is defined in the table captions is within the certified error bar of the standards (\pm 5%) with the exception of standard material G582 by a significant amount for both instruments. This leads us to question the quality of this standard. The analysis statistics are summarized as follows:

Standard ID	<u>Statistic</u>	Bench-top	<u>Handheld</u>
G582	Relative counting error 2σ (calculated)	2.6%	3.4%
	RSD of measurements 2σ	2.9%	2.4%
	Accuracy relative to given standard value	20.2%	12.9%
G581	Relative counting error 2σ (calculated)	3.2%	2.6%
	RSD of measurements 2σ	1.7%	2.2%
	Accuracy relative to given standard value	6.9%	1.7%
E118	Relative counting error 2σ	1.4%	1.6%
	RSD of measurements 2σ	6.1%	1.6%
	Accuracy relative to given standard value	-2.1%	4.8%
RSD = Relati	ive Standard Deviation		

	Zn thicknes	s Given	Bench-top	Analyses	Stat error	Accuracy	Handheld	Analyses	Stat error	Accuracy
<u>Std.</u> Material	um	uin	иm	uin	2 0		um	uin	2 σ	
	<u>, mn</u>	<u>µ</u>	<u>an</u>	<u>µ11</u>	20		2.00	<u>400</u>	20	
G582	2.625	105	3.15	126			3.00	120		
			3.08	123			2.95	118		
			3.18	127			3.00	120		
			3.15	126			2.95	118		
			3.15	126			2.95	118		
			3.15	126			2.98	119		
			3.25	130			2.95	118		
			3.20	128			2.93	117		
			3.20	128			3.00	120		
			3.13	125			2.98	119		
			3.15	126			2.93	117		
			3.15	126			2.98	119		
			3.18	127			2.93	117		
			3.15	126			2.95	118		
			3.08	123			3.00	120		
			3.18	127			2.93	117		
			3.08	123			2.93	117		
			3.15	126			2.93	117		
			3.18	127			2.98	119		
			3.23	129			3.05	122		
Average			3.16	126		20.2%	2.96	119		12.9%
2 σ			0.09	3.7			0.07	2.8		
%RSD			2.9	2.9	2.6		2.4	2.4	3.4	

Table 2

Table 2: Twenty repeat analyses of G582 with the bench-top unit and handheld unit. Stat Error is predicted by Zn counting error % Relative Standard Deviation at 95.4% confidence. Accuracy is defined as Average Analyzed Thickness – Given Thickness / Given Thickness x 100 (%)

	Zn thickr	ess Given	Bench-top	Analyses	Stat error	Accuracy	Handheld	Analyses	Stat error	Accuracy
<u>Std.</u> Material	um	uin	um	uin	2 σ		um	uin	2 σ	
<u>6581</u>	77	308	<u>8 10</u>	324	20		7.83	<u>213</u>	20	
0001	1.1	500	8.33	333			7.00	304		
			0.00	221			7.00	212		
			0.20	207			7.05	014		
			0.10	327			7.65	314		
			8.18	327			7.95	318		
			8.13	325			7.85	314		
			8.28	331			7.65	306		
			8.50	340			7.93	317		
			8.10	324			7.70	308		
			8.15	326			7.93	317		
			8.33	333			7.80	312		
			7.98	319			7.85	314		
			8.45	338			7.83	313		
			8.20	328			7.93	317		
			8.25	330			7.93	317		
			8.43	337			7.93	317		
			8.23	329			7.85	314		
			8.28	331			7.88	315		
			8.10	324			7.68	307		
			8.23	329			7.93	317		
Average			8.23	329		6.9%	7.83	313		1.7%
2 σ			0.26	10			0.20	8		
%RSD			3.2	3.2	1.7		2.6	2.6	2.2	

Table 3

Table 3: Twenty repeat analyses of G581 with the bench-top unit and handheld unit. Stat Error is predicted by Zn counting error % Relative Standard Deviation at 95.4% confidence. Accuracy is defined as Average Analyzed Thickness – Given Thickness / Given Thickness x 100 (%)

									Stat	
	Zn thickne	ess Given	Bench-top A	analyses	Stat error	Accuracy	Handheld A	nalyses	error	Accuracy
Std. Material	<u>μm</u>	<u>µin</u>	<u>µm</u>	<u>µin</u>	<u>2 σ</u>		<u>µm</u>	<u>µin</u>	<u>2 σ</u>	
E118	20.5	820	19.48	779			21.70	868		
			21.50	860			21.23	849		
			20.18	807			21.78	871		
			20.50	820			21.63	865		
			19.80	792			21.68	867		
			20.45	818			21.48	859		
			19.28	771			21.63	865		
			19.68	787			21.30	852		
			18.93	757			21.68	867		
			20.78	831			21.25	850		
			20.40	816			21.40	856		
			20.13	805			21.83	873		
			19.50	780			21.45	858		
			20.28	811			21.45	858		
			19.35	774			21.35	854		
			20.75	830			21.43	857		
			20.20	808			21.43	857		
			20.10	804			21.50	860		
			19.70	788			21.40	856		
			20.40	816			21.33	853		
Average			20.07	803		-2.1%	21.49	860		4.8%
2 σ			0.61	49			0.35	14		
%RSD			6.1	6.1	1.4		1.6	1.6	1.6	

Table 4

Table 4: Twenty repeat analyses of E118 with the bench-top unit and handheld unit. Stat Error is predicted by Zn counting error % Relative Standard Deviation at 95.4% confidence. Accuracy is defined as Average Analyzed Thickness – Given Thickness / Given Thickness x 100 (%)

The Zn plated Fe standards G434, E105, E107, E117, and E120 were each analyzed 3 times with each instrument. These analyses are presented in Table 5. Accuracy of the Handheld analyses are all within the standard accuracy with the exception of the standard E120, in which case the Zn thickness is approaching infinite thickness to the escape depth of for the geometry of both analyzers. When approaching infinite thickness, sensitivity thickness drops logarithmically – the slope flattens. Such that, a small count change will effect a large change in the calculated thickness. This effect is graphically represented in Figure 3, which shows the ratio of the measured Zn intensity (I) to the infinitely thick Zn intensity, (I_{∞}) for the thickness range. As can been seen in this figure, although the benchtop has better sensitivity to thickness for the thinner end of the range (steeper slope), the handheld has a greater range and therefore, better sensitivity at that thicker end of the range – the bench-top is 97% of infinite thickness at 35 μ m of Zn, whereas, the handheld is 85% of infinite thickness at this point and hence the results obtained from the measurement of standard E120 where one of the benchtop analyses generated a greater than range (too thick) message. The slope / range differences between the two instruments are primarily result of incident beam filtering of the handheld (the bench-top had no beam filter for these measurements), and sample-to-detector take-off angles – the handheld has a greater take-off angle than the bench-top.

	Zn thic	ckness						
	Giv	/en	Bench-top	Analyses	Accuracy	Handheld	Analyses	Accuracy
Std. Material	<u>μm</u>	<u>µin</u>	<u>μm</u>	<u>μin</u>		<u>μm</u>	<u>µin</u>	€
G434	5.1	204	5.68	227		5.10	204	
			5.68	227		5.25	210	
			5.63	225		5.35	214	
Average			5.66	226	10.9%	5.23	209	2.6%
E105	6.675	267	7.33	293		6.88	275	
			7.10	284		6.95	278	
			7.33	293		6.88	275	
Average			7.25	290	8.6%	6.90	276	3.4%
E107	9.625	385	10.60	424		9.88	395	
			10.20	408		9.70	388	
			10.50	420		9.88	395	
Average			10.43	417	8.4%	9.82	393	2.0%
E117	14.18	567	14.23	569		14.43	577	
			14.65	586		14.55	582	
			14.73	589		14.45	578	
Average			14.53	581	2.5%	14.48	579	2.1%
E120	25.6	1024	24.10	964		27.43	1097	
			23.68	947		27.73	1109	
			>range	>range		27.80	1112	
Average			23.89	956	-6.7%	27.65	1106	8.0%

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Accuracy is defined as Average Analyzed Thickness – Given Thickness / Given Thickness x 100 (%)

Figure 3



Figure 3 shows the I / I $_{\infty}$ Zn curves for the Handheld (HH) and Bench-top (Bench) over the measurement range. The unfiltered beam of the bench-top provides better sensitivity (steeper slope) at the thin end of the range. The filtered beam and greater sample-to-detector take-off angle of the handheld provides improved sensitivity at the thick end of the range, and extends the range.

We conclude from the preceding results that the handheld and bench-top instruments demonstrate generally equivalent analytical performance for the measurement of coating thickness of materials having analysis areas of infinite area to the incident beam the instrument.

As alluded to earlier in this paper, perhaps the most significant application difference between a handheld XRF instrument and bench-top XRF unit when measuring coating thickness is the analysis area and therefore the types of samples that can be accurately analyzed.

Analysis of Thin-Film Structures of Less Than Infinite Area to the Handheld Beam:

So far we have presented the measurement of coatings with XRF using the fluorescence from the coating elemental component(s). On page 5 of the paper the idea that using absorption of the substrate fluorescence simultaneously with layer emissions the limitation of analyzing only samples of infinite area to the beam may be overcome. To elaborate, for a given layer thickness, if the sample area is less than the beam area the layer fluorescence is less than if it were infinite

to the beam and the analysis algorithm calculates a thinner coating. For this same condition the substrate emission is also less, which would seem like more absorption and is interpreted by the algorithm as a thicker film. If the substrate thickness is fixed (infinitely thick), which in many applications it is, then layer thickness can be determined by solving simultaneous equations for film thickness using substrate absorption and layer emission (layer-to-substrate ratioing).

To demonstrate this, two sample types that would usually require collimated beam analysis were measured with our bench-top unit and collimated beams to meet the analysis area of infinite area to the beam condition, and our handheld with nominal 7 mm diameter beam. The samples were a set of Au / Ni plated copper pins and Ni plated copper lead frame strip shown in Figure 4. As indicated in these figures the contiguous plated areas are substantially less than the handheld beam area.



Figure 4

Figure 4: White oval provides an estimate of the handheld incident beam area.

The lead frame strip consisted of eight frames. Ten random measurements were made with the bench-top system – an average and standard deviation (2σ) calculated. Each of the eight fames were measured with the handheld – measurements representing an average Ni thickness of the frame. The results are compared in Table 6 and compare very well – handheld to bench-top values are within 10% of each other.

As with the lead frame, ten random points along the length of the Au / Ni plated pins were measured with the bench-top unit. As is often observed with pins plating was not uniform – thicker towards the tips with gradation down towards the Sn and eutectic points. The Au / Ni plated ends of the pins were measured six times with the handheld using various orientations of the beam to the pins. The bench-top and handheld results of these measurements are compared in Table 5. Although average Au layer thicknesses compare very well – within 4%, the handheld average, Ni thickness is nearly 75% greater than that determined with the bench-top. Geometric effects, which could impact the handheld results may play into this, but it is not clear why they would be so prominent in the Ni measurement and not the Au. The true value at the time of this writing is unknown.

Leed Frence	Bench Thick	top Ni ness	Handheld Ni Thickness		
Lead Frame		win		uin	
Strip	<u>µm</u>	<u>µm</u>	<u>µm</u> 1.05	<u>um</u>	
			1.65	66	
			1.60	64	
			1.55	62	
			1.60	64	
			1.53	61	
			1.73	69	
			1.55	62	
			1.58	63	
Average	1.78	71	1.60	64	
2σ	0.30	12	0.13	5	
	Au thckr	ness μm	Ni thickr	ness μm	
Au / Ni / Cu					
Pins	Bench-top	Handheid	Bench-top	Handneid	
		1.13		5.35	
		1.58		6.23	
		1.60		6.25	
		1.48		6.05	
		1.45		6.00	
		1.45		5.98	
Average	1.40	1.45	3.43	5.98	
2σ	0.26	0.34	0.85	0.66	

Table	6
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Table 6: Comparison of results from samples having infinite area to the collimated beam of the bench-top unit but less than infinite area to the beam of the handheld unit. The less than infinite area condition is adjusted for by using a unique layer emission to substrate emission ratioing algorithm.

Conclusions:

As noted at the beginning of this paper the most obvious application enabling benefits of handheld XRF, and therefore, basis for selection are analysis location – taking the testing lab to the sample, and sample size – it need not fit in the box. The measurements presented here demonstrate that handheld XRF analytical performance for coating thickness measurement is equivalent to accepted benchtop XRF configurations when the measurement area is of infinite area to the handheld beam. Where this may seem to be an application limitation, employing unique layer-emission-to-substrate-emission fundamental parameter algorithms indicate that smaller, less than infinite area to beam samples can be accurately measured for coating thickness. This ability presents many application possibilities for portable as well as fixtured handheld units. For instance, the plating thickness measurement of in-process lead frame or pin strips with a fixtured handheld unit or probe head.