Coating Thickness Measurement of Thin Gold and Palladium Coatings on Printed Circuit Boards using X-Ray Fluorescence

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- The Measurement Application
- Measurement Requirements
- Measurement Problems
- Measurement Results
- Reference Samples
- Conclusions

Measurement Application Au/Pd/Ni(P)/Cu/..

- **Layer thickness as described in IPC 4556/2**
  - **40 - 125 nm Au (1.6 -5u'') thinner for lead frame applications**
  - **50 - 150 nm Pd (2-6u'')**
  - **3 - 6 µm Ni(P) (120u''-240'')**
- **Base Materials:**
  - **Cu/Epoxy + Br + Fiberglas**
  - **Cu/Ceramic**
  - **Cu/Polyimide**
  - **CuFe2**
  - **Cu/???**
- **Copper in PCB's can occur as multiple layers.**
  - **Influences Cu Kα/Kß radiation ratio - Accuracy**

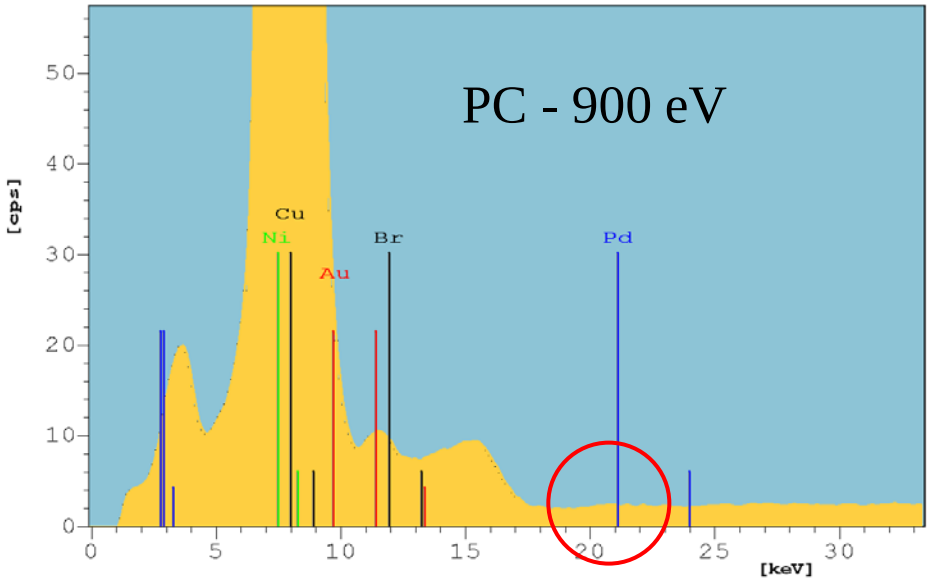
Measurement Requirements

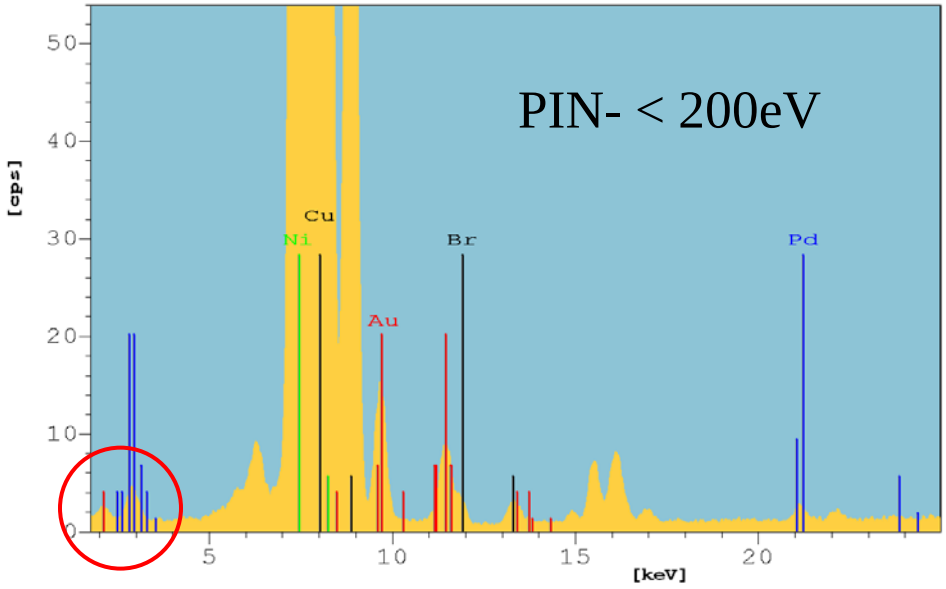
- **Meet standard/part specifications**
- **Sufficiently small standard deviation (instrument precision) to meet Gage R&R requirements- T/s value**
- **Ensure minimum plating thickness requirement with minimum over plating**
- **Accuracy**
- **Reproducibility**
- **Measurement spot size often < 0.1 mm (Polycapillary)**
- **Accurate positioning table < 5 um**

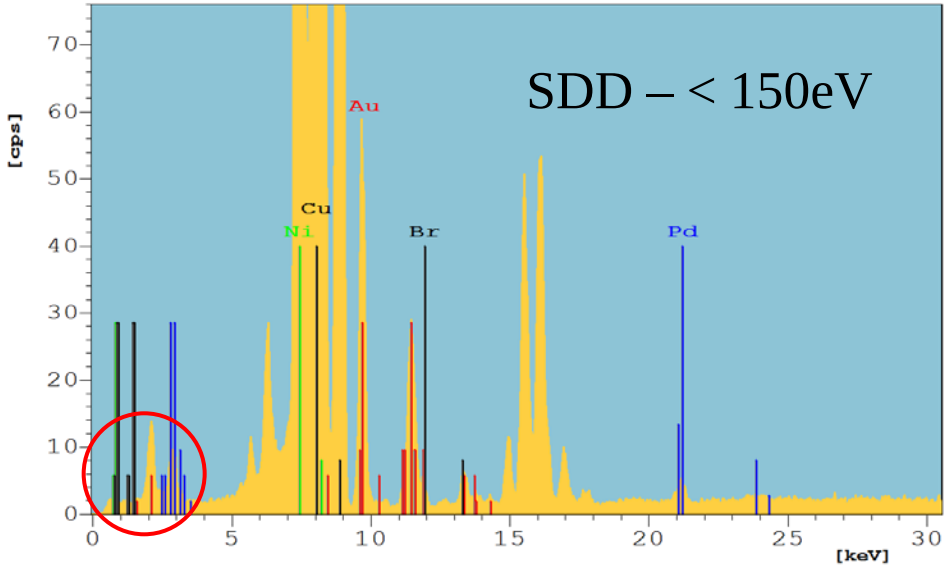
XRF-Instrument considerations

- **Detector technology (Proportional Counter PC, PIN-Diode, SDD)**
- **Spot size defined by collimator or X-ray Optic (Polycapillary)**
- **Automate measurement with programmable x-y-z table**
- **Software requirements to overcome challenges of the application**
  - **Peak Overlap (Ar-K & Pd-L), Cu-thickness, Br-correction, Background scattering, Pile-up, Interference from Bragg-Peaks**

Comparison of Spectra

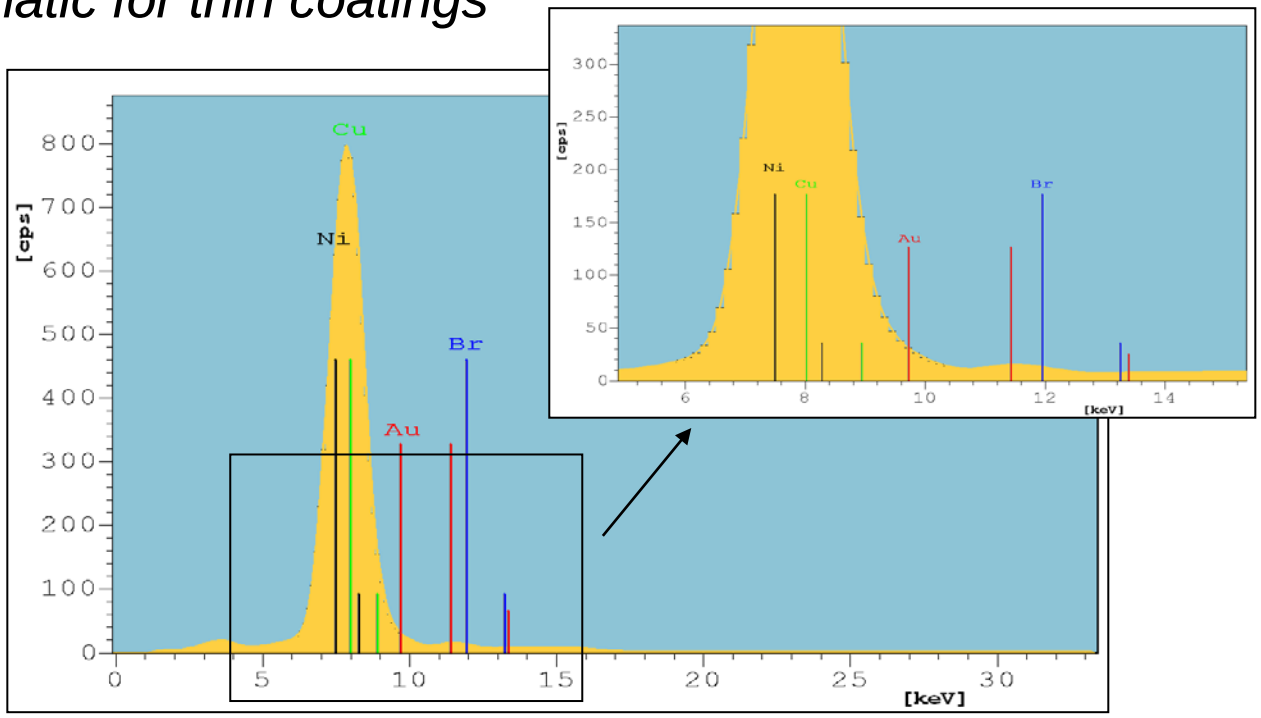






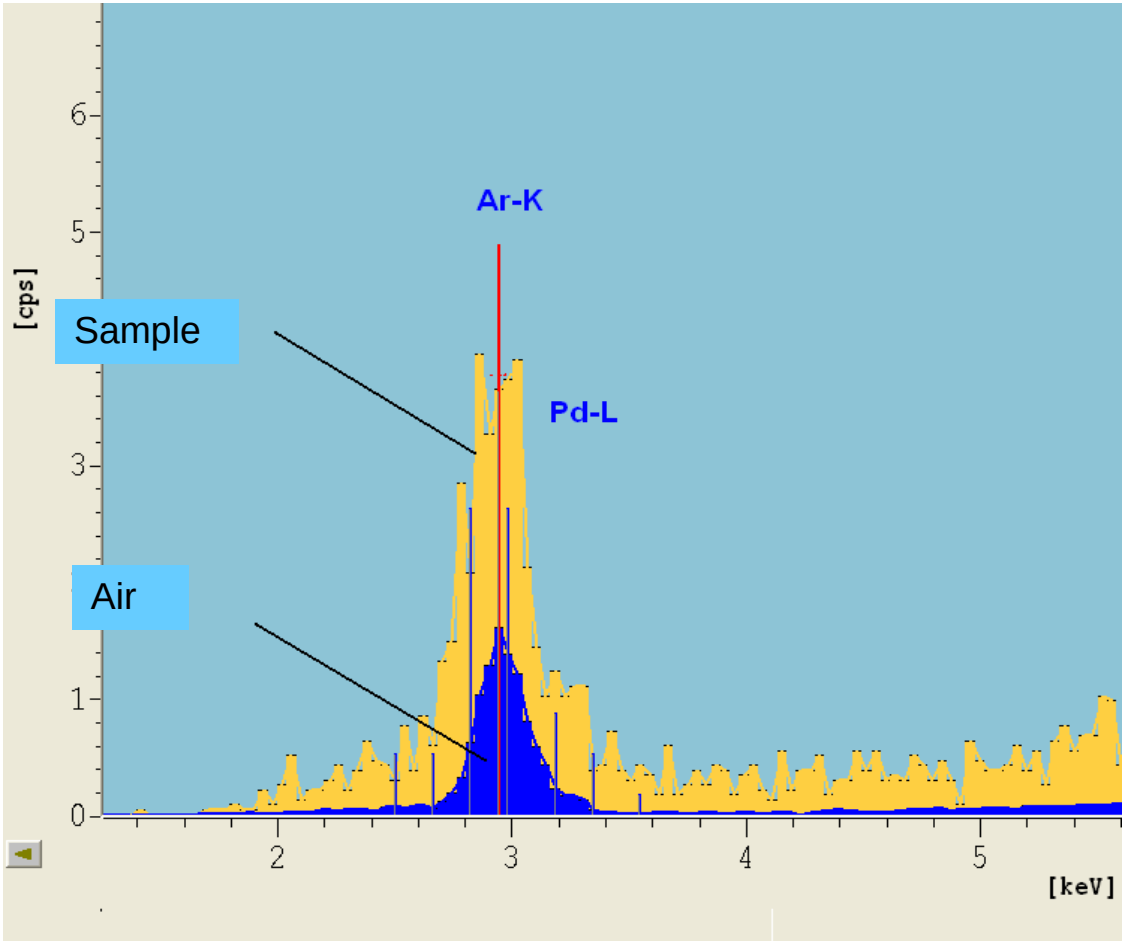
Measurement Problems-Peak overlap

Au-Lα peak overlaps with Cu-Kα peak
Au-Lβ peak overlaps with Br-Kα peak.
Problematic for thin coatings



Measurement Problems

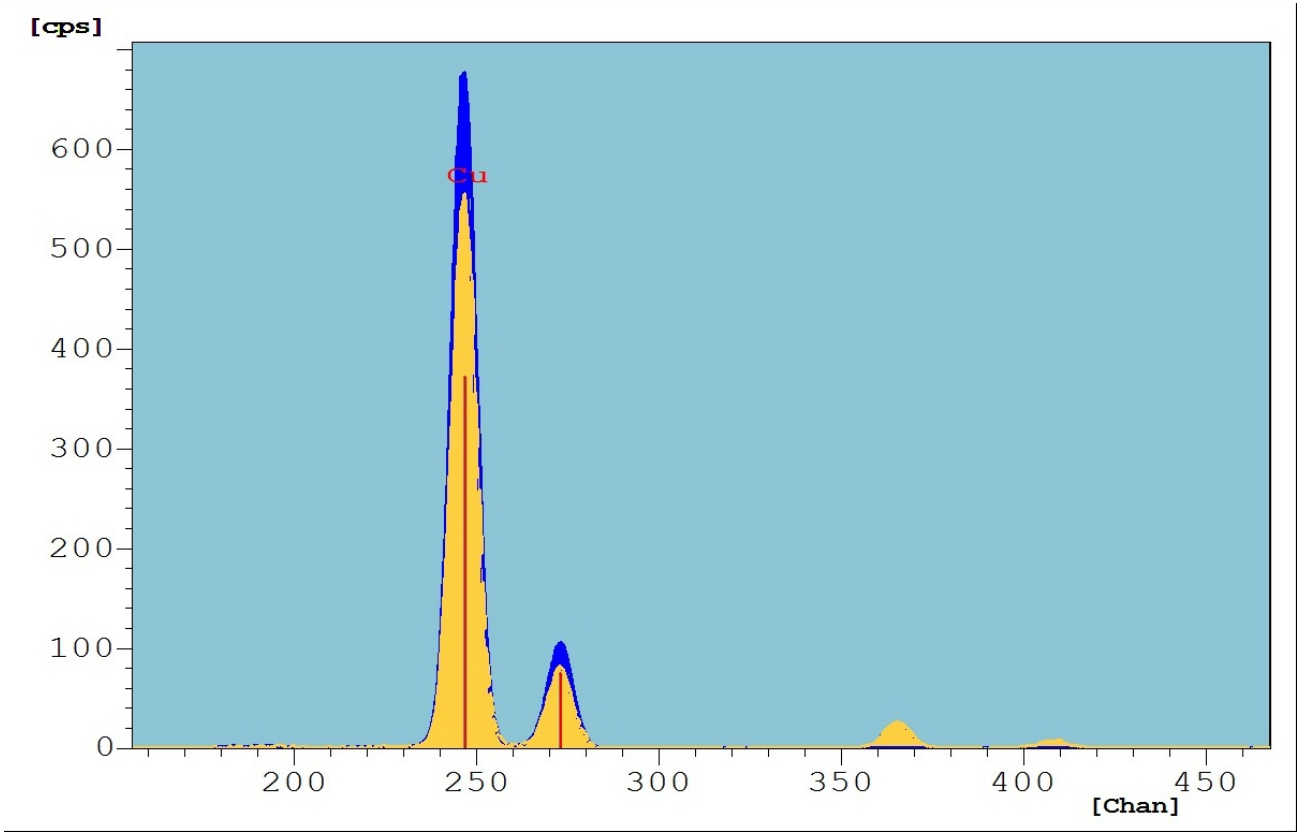
- Overlap of Ar-K – Pd-L radiation
- SDD- Pd resolved
- Minimize Ar-peak



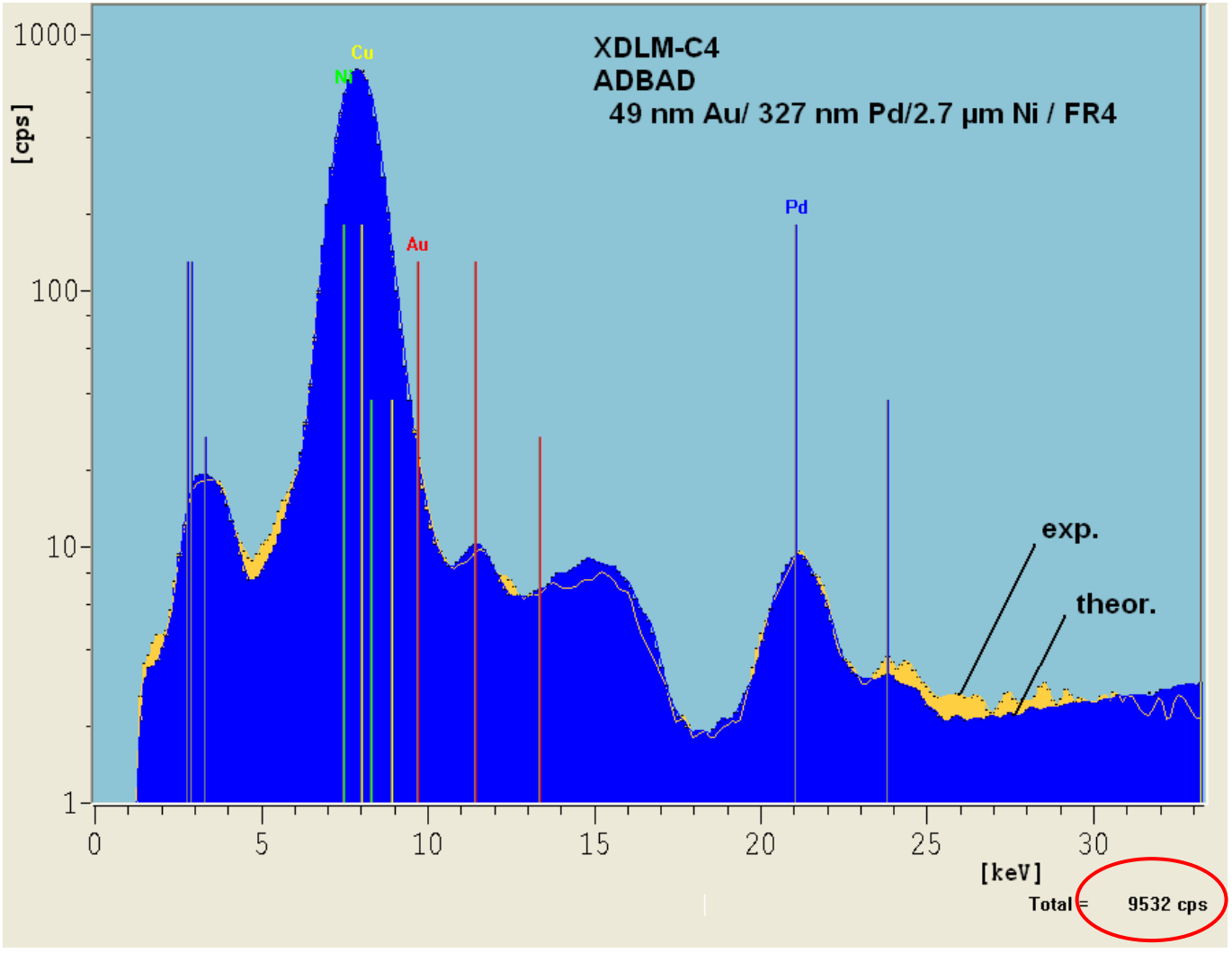
Measurement Problem Cu Kα/Kß-ratio

Infinite Copper - 6.44
Multilayer PCB - 6.76

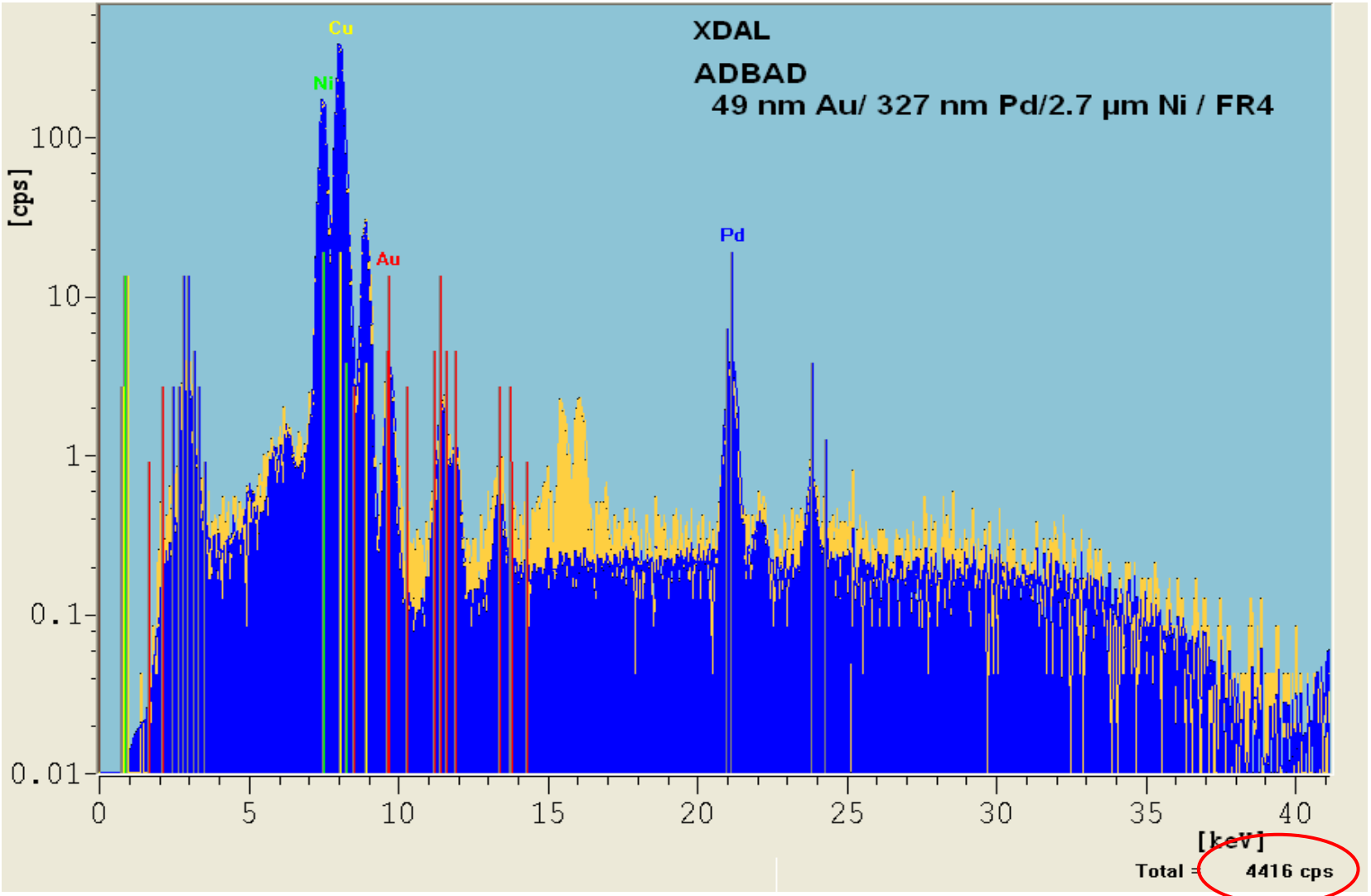
Measure Copper Thickness!



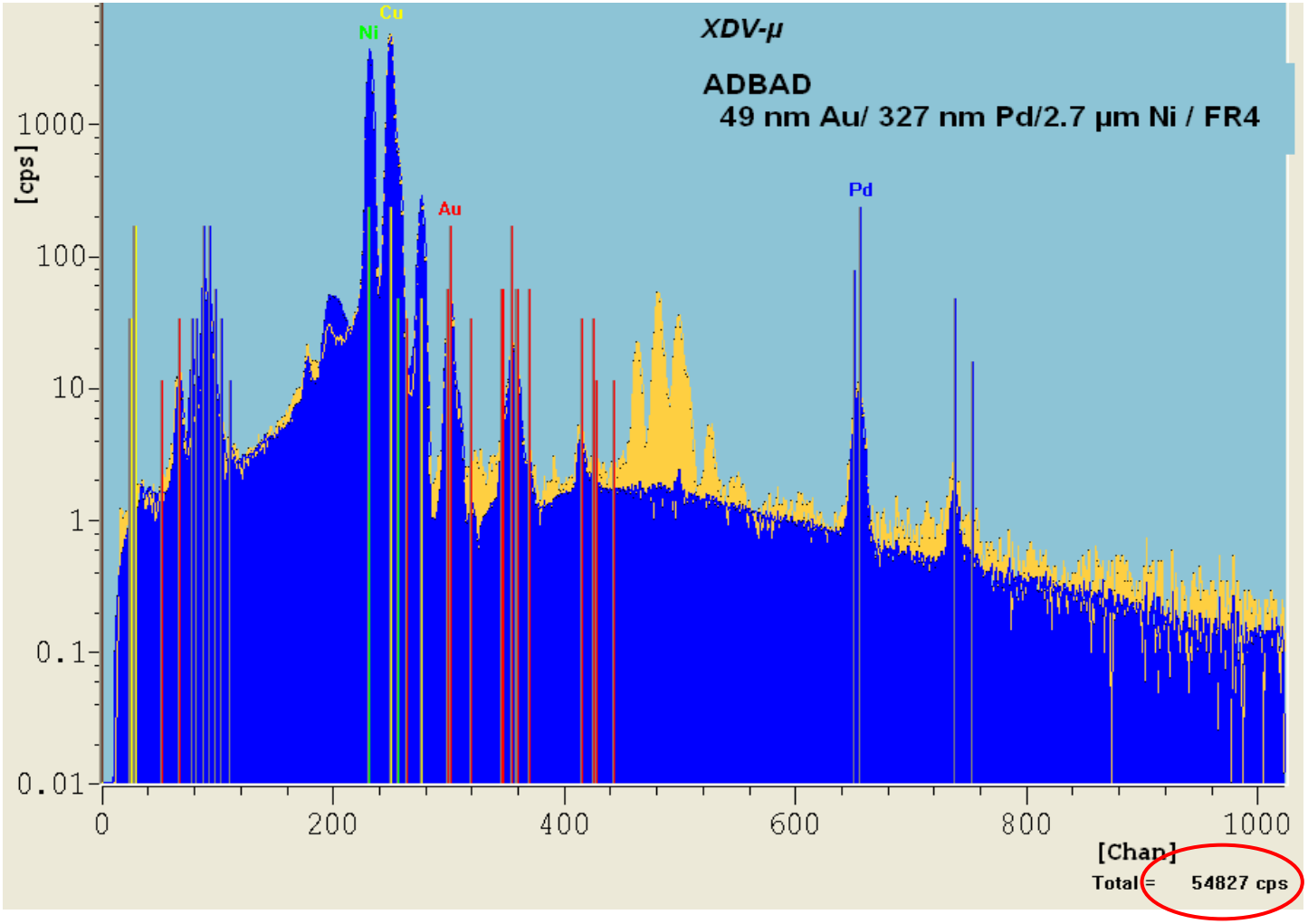
Detector (PC, PIN, SDD) 900 eV resolution



Detector (PC, PIN, SDD) 200 eV Resolution



Detektor (PC, PIN, SDD) 140 eV resolution



- **Ar-K – Pd-L-Overlap**

  Better detector resolution SDD. Minimizing Ar-Peaks by optimized instrument design

- **Background Scattering**

  Correction by Software. For flexible boards special sample fixture

- **Pile-up**

  Intensive Pile-ups corrected by software

- **Bragg-Peaks**

  Eliminated during analysis-always at same position

- **Cu in several Layers -> Kα/Kß-ratio**

  Measure Cu- thickness

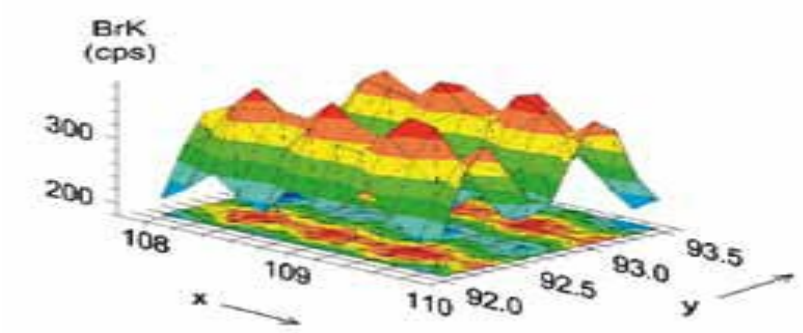
Instrument Comparison

		XDLM-237	XDAL	XDV-μ
	Detector	PC	PIN	SDD
	Intensity (cps)	9500	4400	55000
	Measurement Spot Size (mm)	0.25	0.35	0.06
Calibration Standards	Standard Deviation			
13 nm Au 49 nm Au	s(Au) [nm]	2.4 2.4	1.2 2.1	0.7 0.4
16 nm Pd 327 nm Pd	s(Pd) [nm]	3.6 6.3	5 8	2.2 1.4
2000 nm Ni 2700 nm Ni	s(Ni) [nm]	46 124	23 17	2.9 2.5
	Measurement conditions: 30 s, 10 Measurements			

Au- measurements „Accurate“ or „True“

-> **Reproducibility**

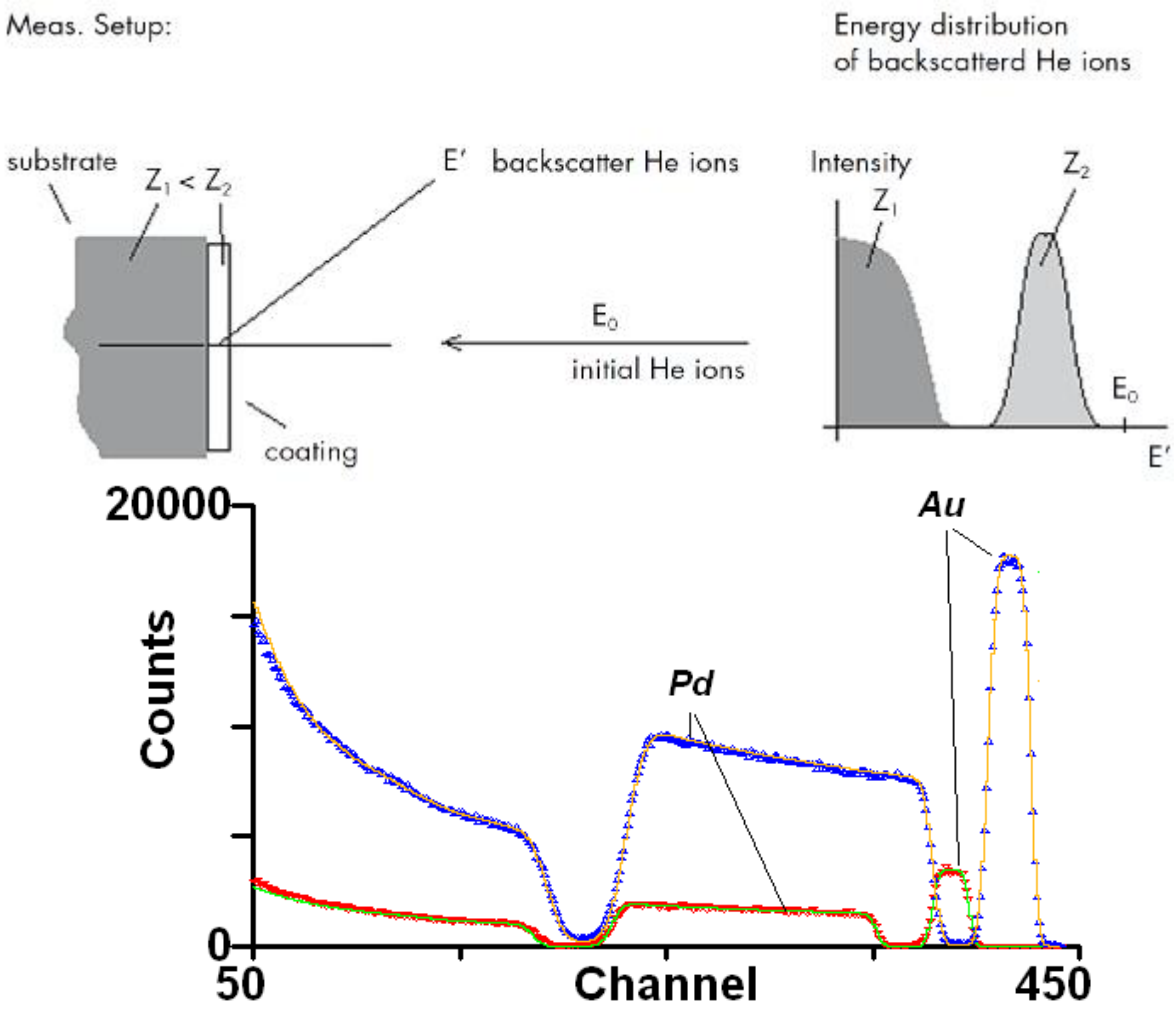
No influence of various substrate materials



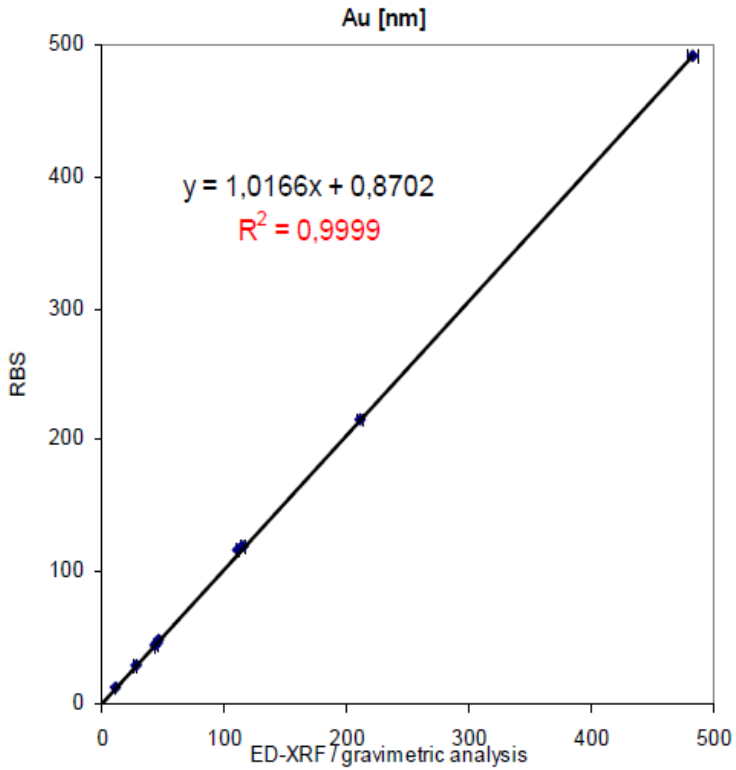
Substrate	Fitting of Scattering Background Cu-Thickness variable With Br- compensation	No Fitting of Scattering Background Cu-Thickness fixed. No Br-Compensation
PCB Epoxy without Bromine	111 (4)	111 (1)
PCB Epoxy with Bromine	112 (4)	**129 (!)** (1)

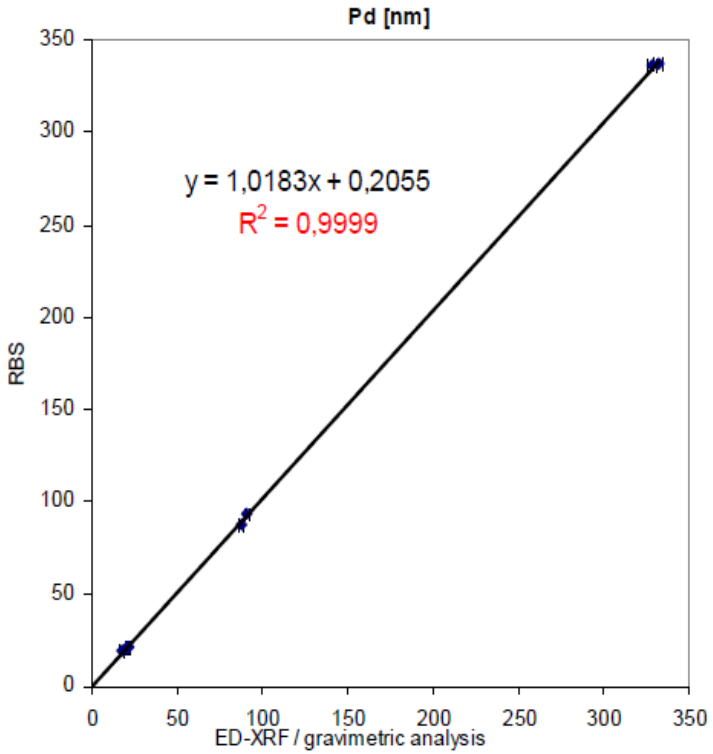
111 nm Au /PCB. Mean and Std.Dev..
X-RAY XDLM®, Collimator 0,3 mm * 0.05 mm calibrated

Making Standards-Rutherford backscattering RBS



Correlation of RBS-XRF and Gravimetric Analysis





Trueness – Tracebility To “Good” Referece Standards With Small Total Measurement Uncertainty

Standard	Au [nm]	u [nm]	Pd [nm]	u [nm]	Ni [nm]	u [nm]
1	213,8	2,6			103,6	4,1
2	486,8	4,7			250,4	8,5
3	117,5	1,3			2510	35
4	114,1	1,3			5710	46
5			21,6	0,6	2101	35
6			87,3	0,9	2363	33
7			333,2	2,6	2263	29
8	48,1	0,7	21,1	0,8	2211	33
9	44,0	0,7	92,1	0,9	2354	35
10	45,8	0,7	331,7	2,7	2693	30
11	11,8	0,2	18,7	0,4	2425	34
12	28,4	0,6			2217	32

Conclusion

- **DD Detector is State of the Art**
- **Software: Addressing all measurement challenges; Measurement Results for Au, Pd and Ni(P), independent of substrate material**
- **Traceability and Reproducibility through Reference Standards**

Instrument Comparison 2

*Measurement Results (Standard deviation and coefficient of variation COV%) for a PCB-Board with 50 nm Au und 24 nm Pd (underneath 2.1 µm Ni/30 µm Cu/Substrate=FR4) for different detectors. Measurement time 25 * 120 s*

Layer	Proportional Counter (0,2 mm Collimator)	PIN Detector (1 mm collimator)	SDD – Detector (1 mm collimator)
50 nm Au	2,2 nm (4,3 %)	0,9 nm (1,8 %)	0,2 nm (0,4 %)
24 nm Pd	3 nm (13 %)	1.2 nm (4,8 %)	0.5 nm (2,1 %)

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Standard Deviation			
s(Au) [nm]	2.4 / 2.4	1.2 / 2.1	0.7 / 0.4
s(Pd) [nm]	3.6 / 6.3	5 / 8	3.2 / 1.4
s(Ni) [nm]	46 / 124	23 / 17	2.9 / 2.5
Measurement conditions: 30 s, 10 Measurements			