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Employing μ-XRF for detection of Palladium defects

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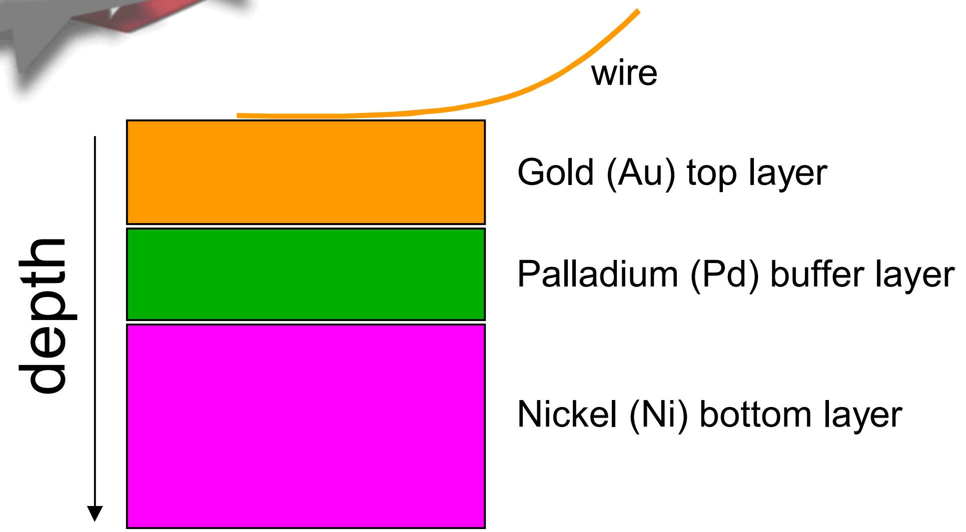
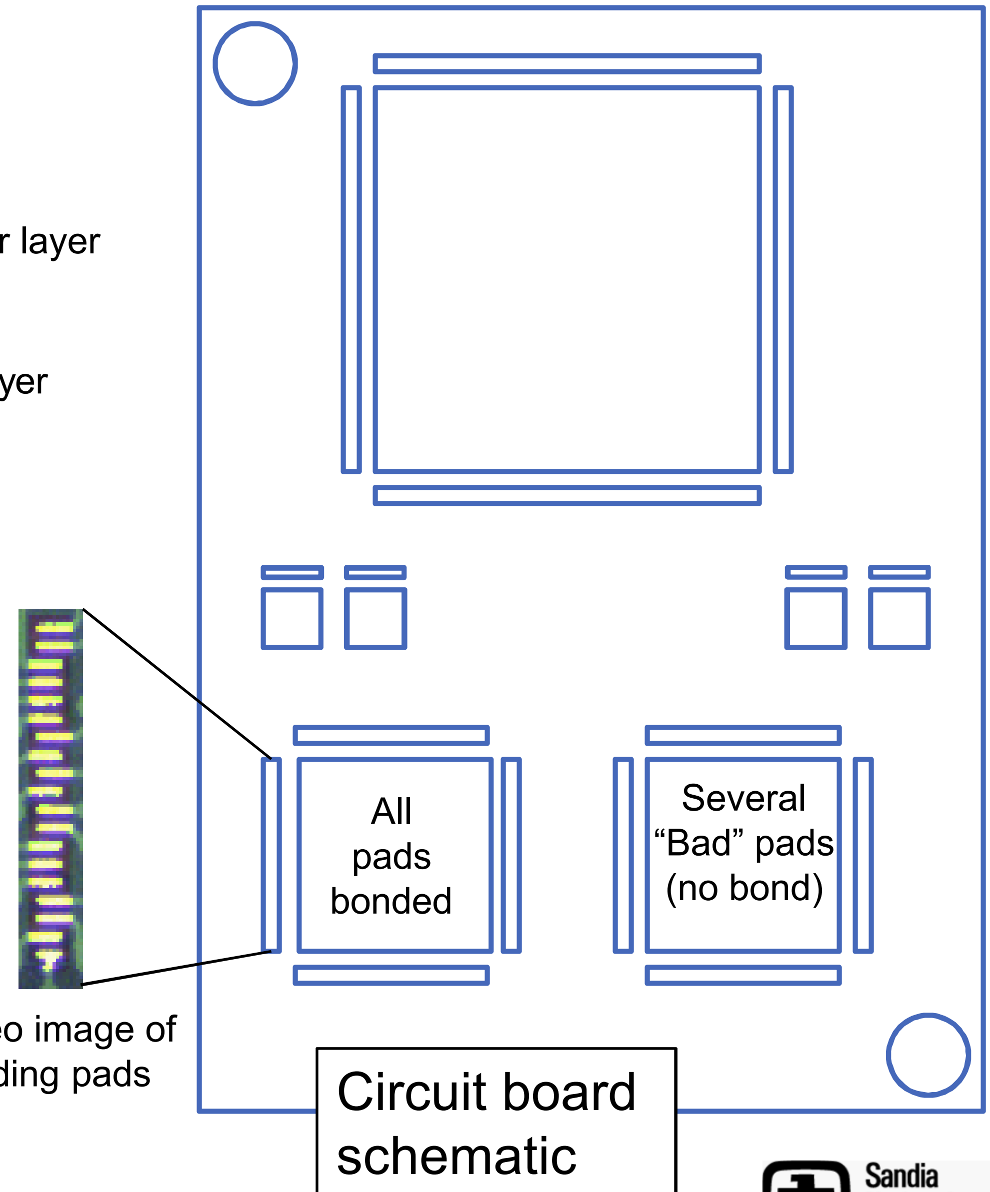
Problem: some wire-bonding pads will not bond.



- Pd layer added to protect Ni migration into Au bond pad.
- Auger spectroscopy can do depth profiling on pads. ☺
- Auger is destructive to pad. ☹
- Can μ-XRF detect sandwiched Pd layer ***non-destructively***?



Video image of bonding pads

Our Plan of Attack

– Use Bruker M4 Tornado μ-XRF to scan circuit boards and look for Pd interlayer on electrode pads.

– Apply Principal Component Analysis (PCA) with Multivariate Curve Resolution (MCR) algorithms to aid data extraction of weak signal embedded in data.

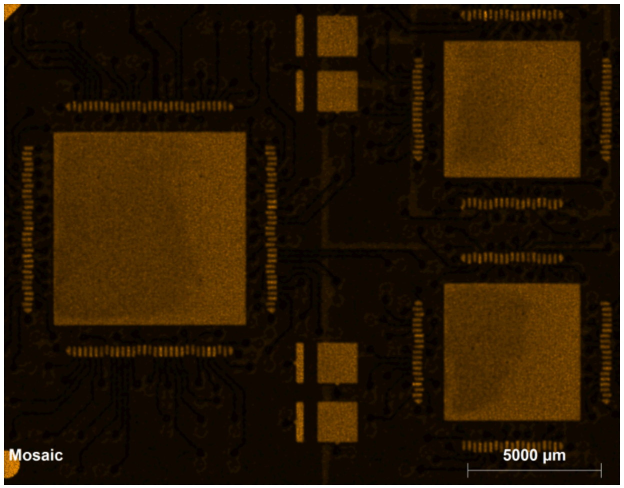
Courtesy Bruker -Nano

Bruker M4 Tornado μ-XRF

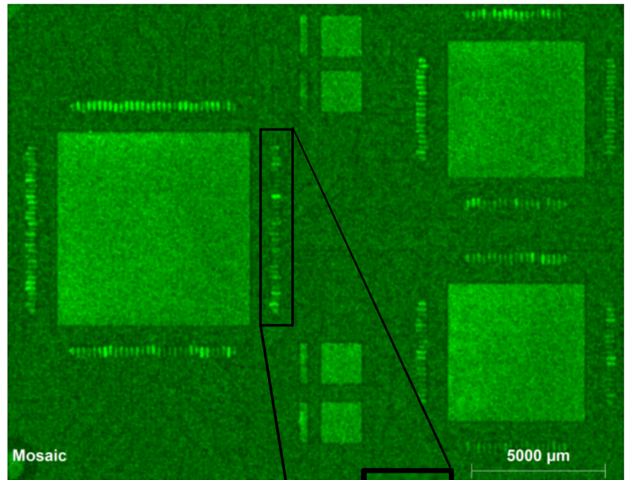
- Rh microfocus source 50 kV/ 600 μA
- High flux polycapillary optic
- ~30 μm spatial resolution
- XFlash® silicon drift detector

Although Cu, Ni, Si, Ba elements dominate the conventional XRF spectrum, we can *still* see spatial dependence of Pd and Au in **keV-slice maps*** even at ~1 wt% levels.

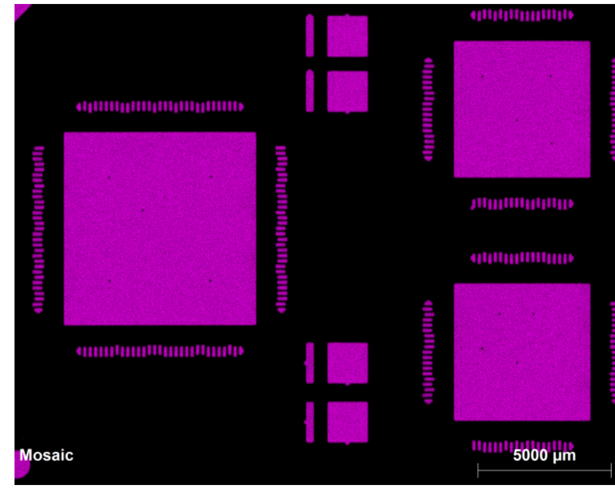
Au Lα keV-slice map



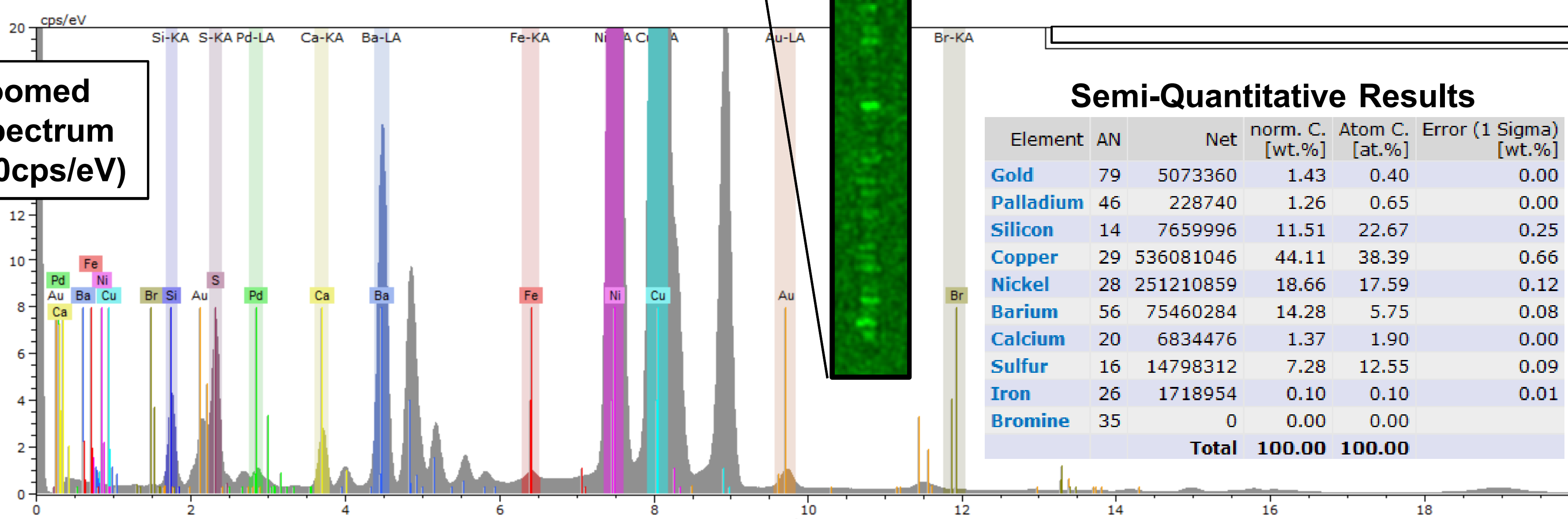
Pd Lα keV-slice map



Ni Kα keV-slice map



Zoomed Spectrum (20cps/eV)

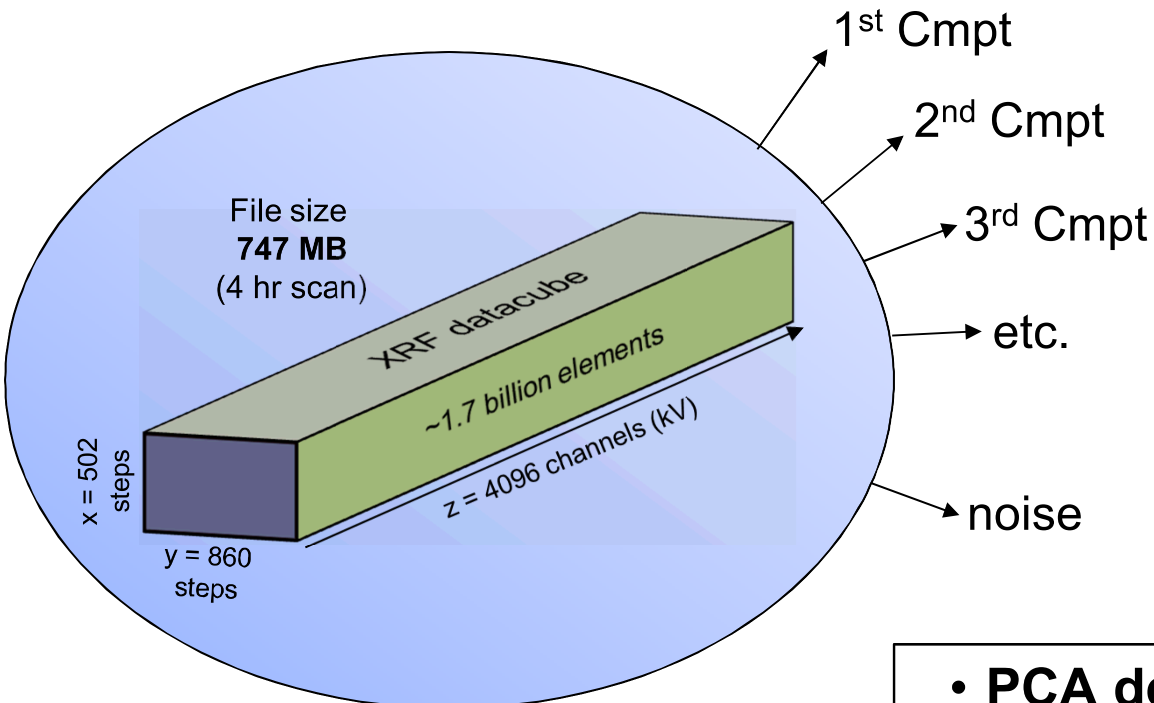


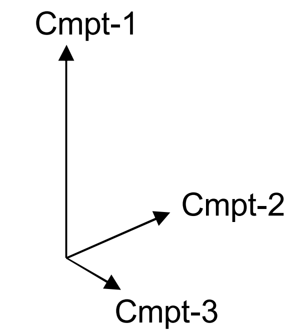
Semi-Quantitative Results

Element	AN	Net	norm. C. [wt.%]	Atom C. [at.%]	Error (1 Sigma) [wt.%]
Gold	79	5073360	1.43	0.40	0.00
Palladium	46	228740	1.26	0.65	0.00
Silicon	14	7659996	11.51	22.67	0.25
Copper	29	536081046	44.11	38.39	0.66
Nickel	28	251210859	18.66	17.59	0.12
Barium	56	75460284	14.28	5.75	0.08
Calcium	20	6834476	1.37	1.90	0.00
Sulfur	16	14798312	7.28	12.55	0.09
Iron	26	1718954	0.10	0.10	0.01
Bromine	35	0	0.00	0.00	
		Total	100.00	100.00	

*from Bruker software output

We employ Principal Component Analysis to reduce ***massive*** μ-XRF datasets





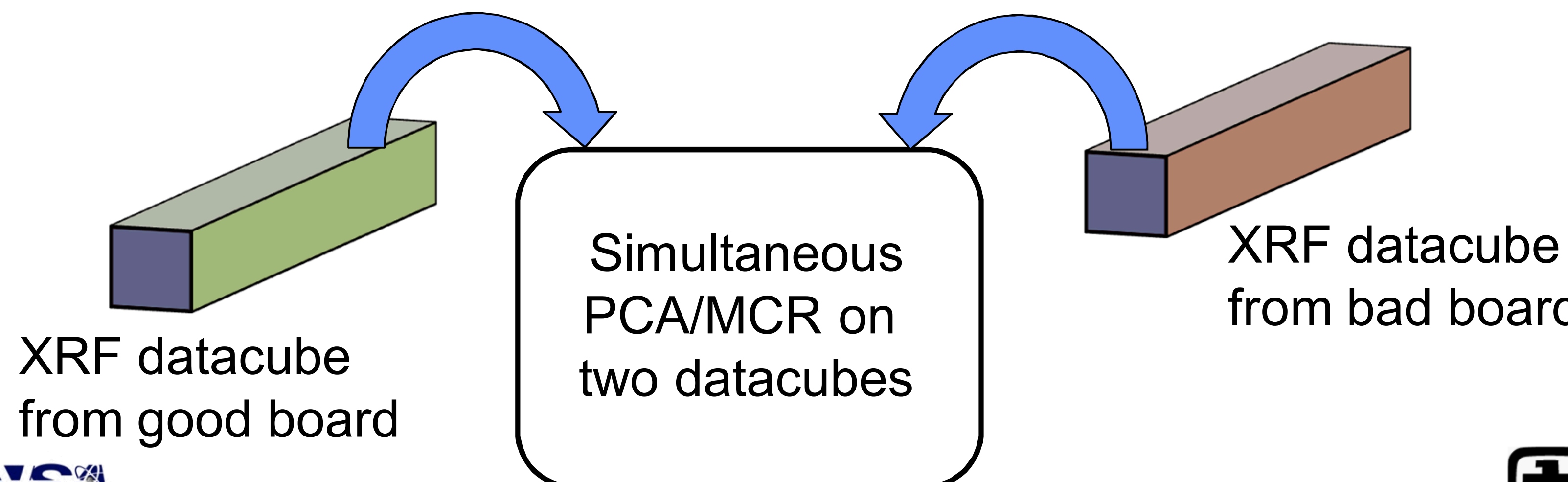
Each derived **component** is mathematically constrained to be orthogonal to others

We assume that the entire XRF datacube can be represented by ***linear combinations*** of all species generating fluorescence signal

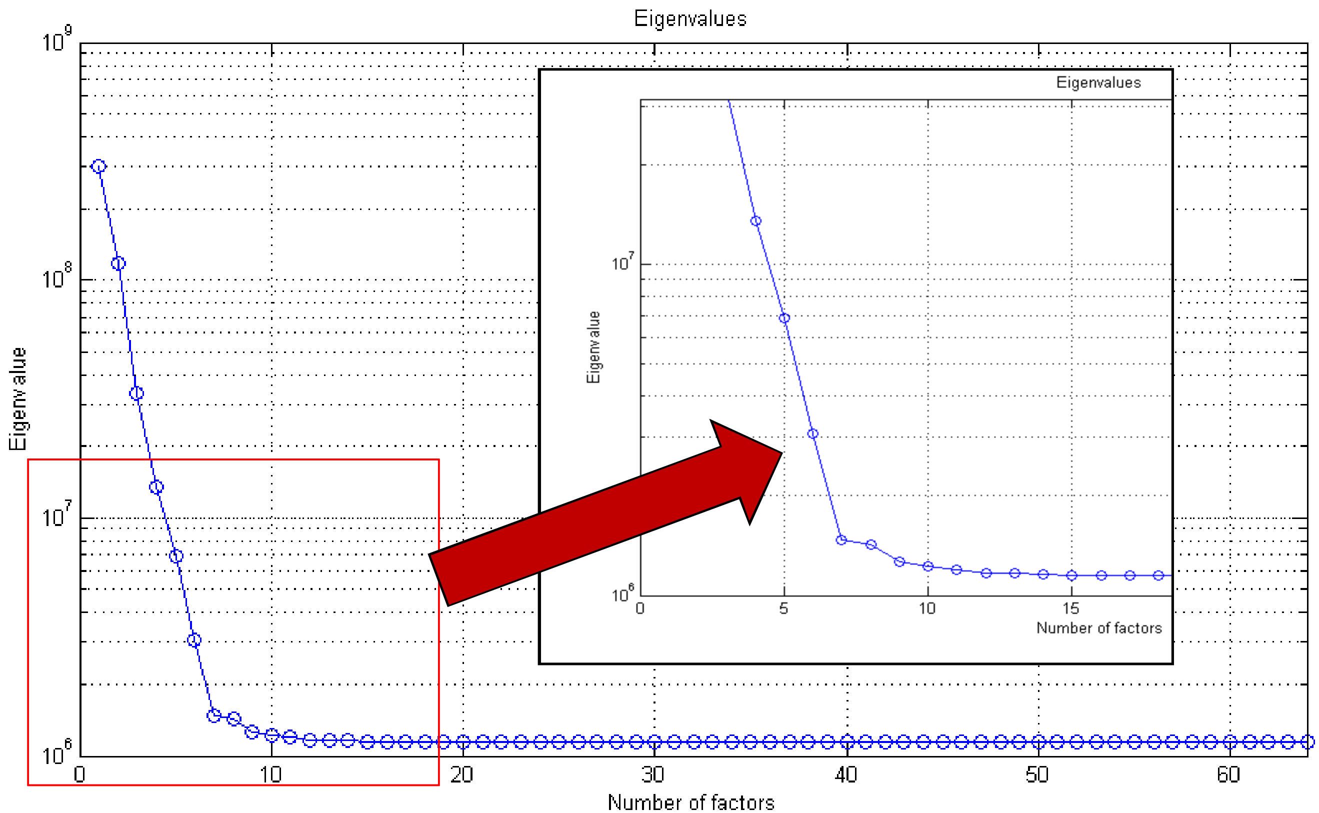
- **PCA decomposes XRF spectra using the entire datacube to find energy features common to given spatial locations**
- **Multivariate Curve Resolution (MCR) helps enable more interpretable results**

Principal Component Analysis (PCA) did not easily extract Pd defects from individual datasets.

- Pd signal is highly *spatially-correlated* to Au and Ni signal
- Low Pd signal and significant Rh/Pd emission-line *overlap*
- The *proportionality* of Au/Pd/Ni ratios may prevent isolation of Pd as a component.
- **Solution**: Perform PCA/MCR with at least two datacubes – a <u>good circuit board</u> and <u>one with problems in Pd pads</u>.

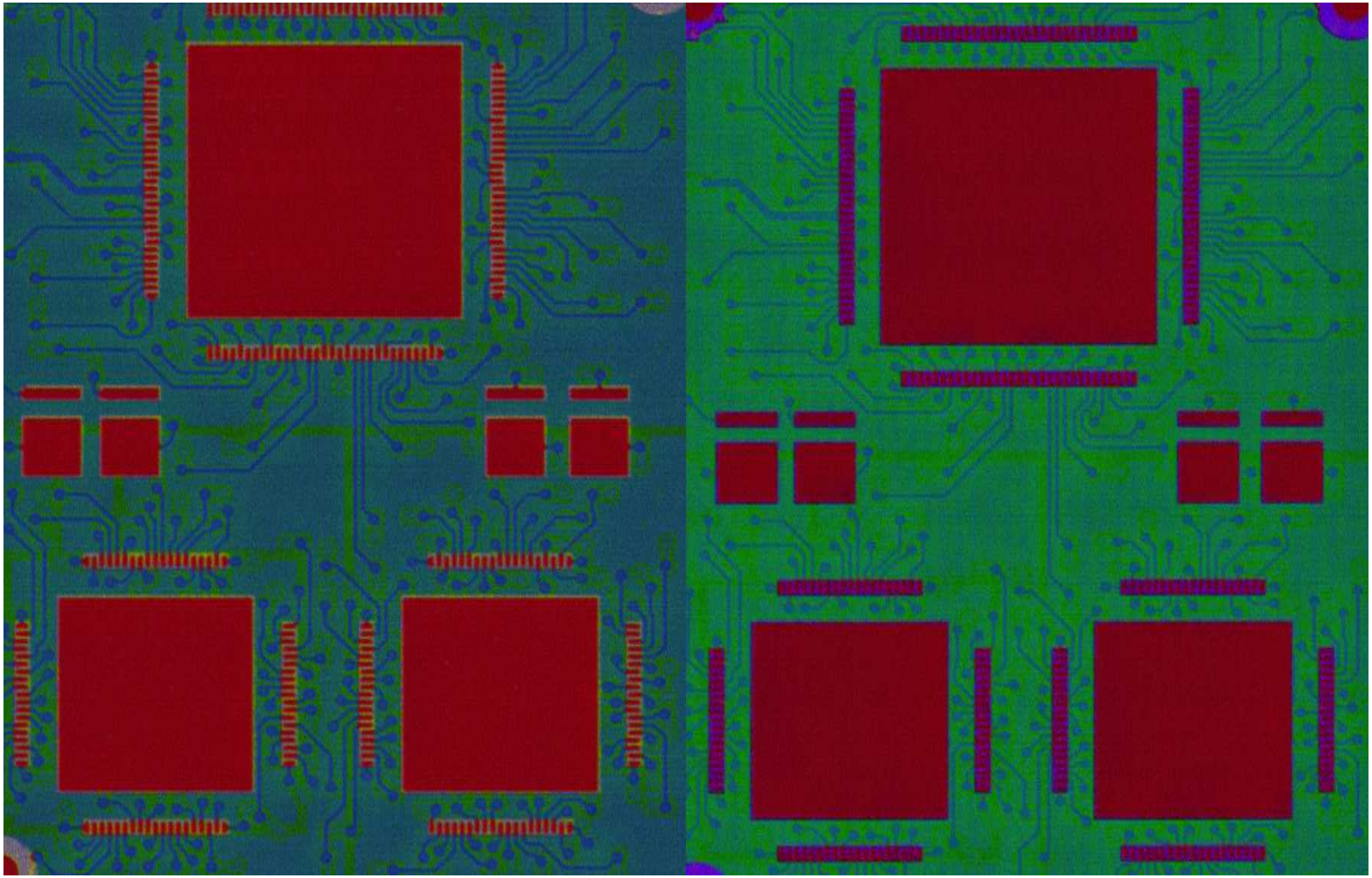


The Eigenvalue analysis suggests at least 9 factors present in the massive dataset for the combined “good-bad” circuit boards



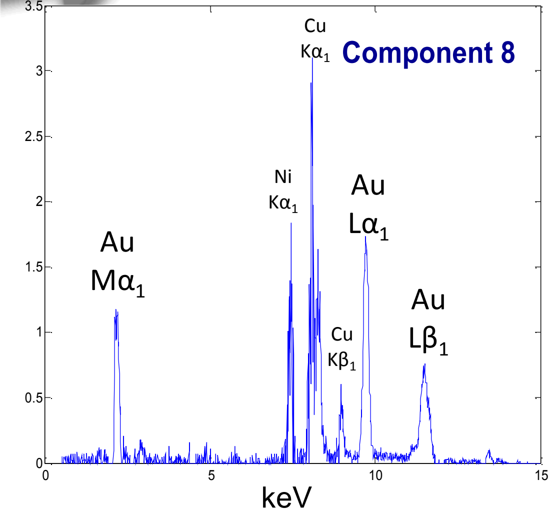
False color chemical maps can be generated from XRF spectrums of extracted components

"Bad" board	"Good" board

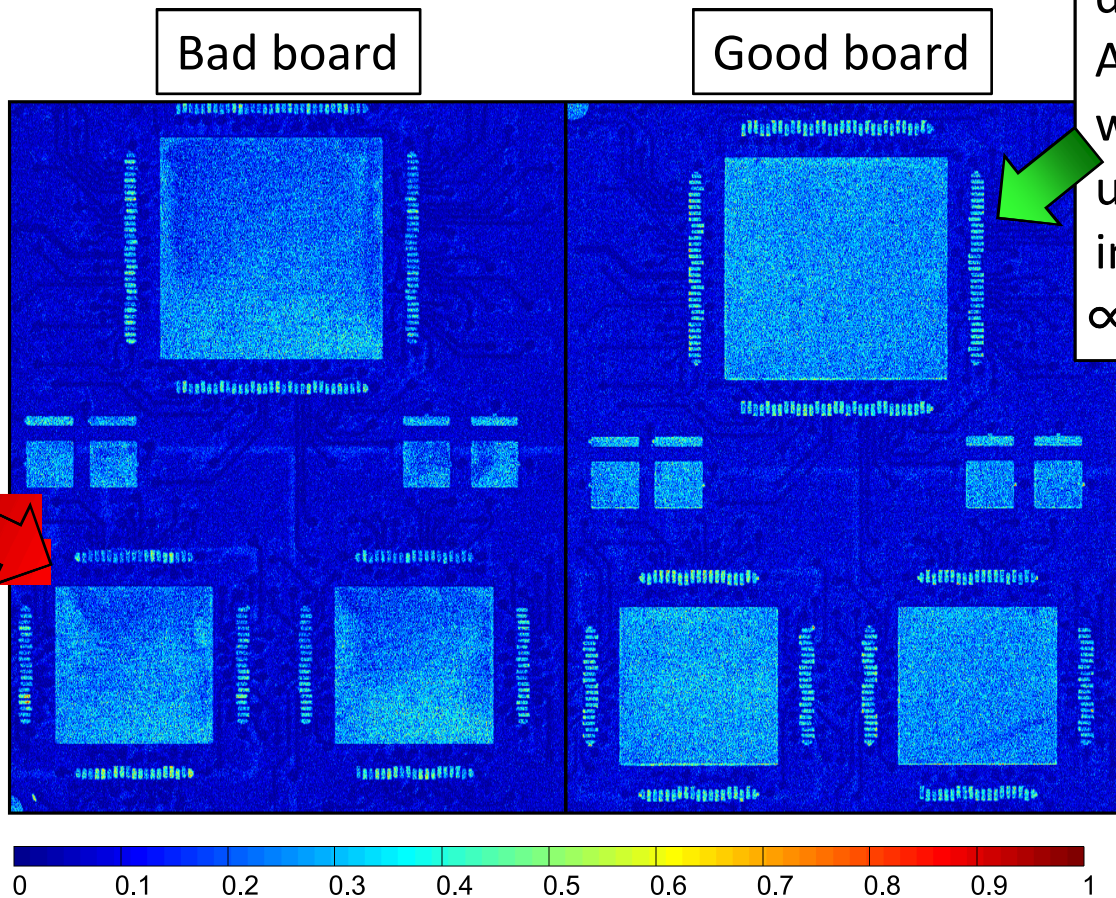


Red = Ni
Green = Ba, S
Blue = Cu
Magenta = Al
Yellow = Si

PCA/MCR of Component 8 shows primarily **Gold signal** in spectrum with some mixing of Cu and Ni

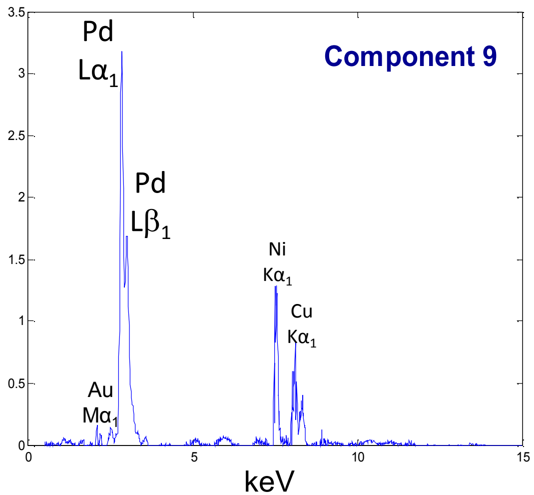


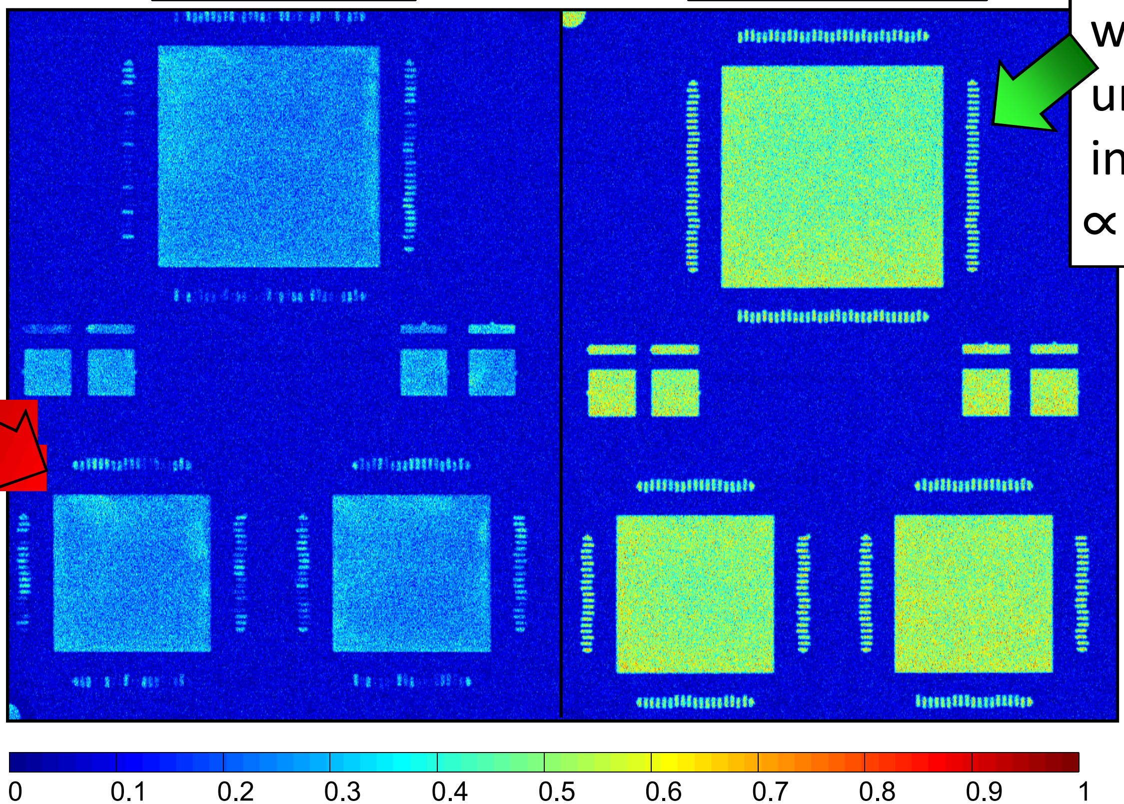
Some Au pads show uneven intensity and location of Au in pad is not always clearly defined.



Clearly defined Au pads with uniform intensity ∝ [Au]

PCA/MCR for Component 9 shows primarily **Palladium signal** in spectrum with some mixing of Cu and Ni





Bad board

Good board

Clearly defined Pd pads with uniform intensity ∝ [Au]

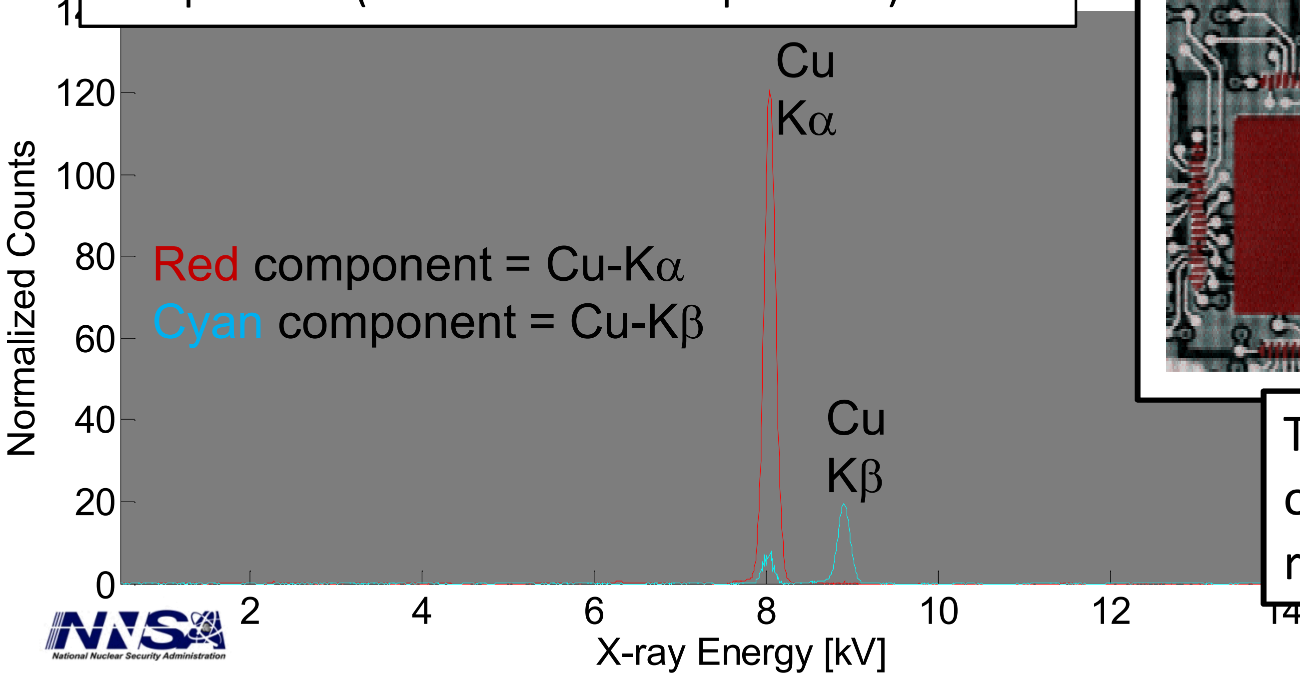
Uneven Pd intensity and some small Pd pads are completely missing.

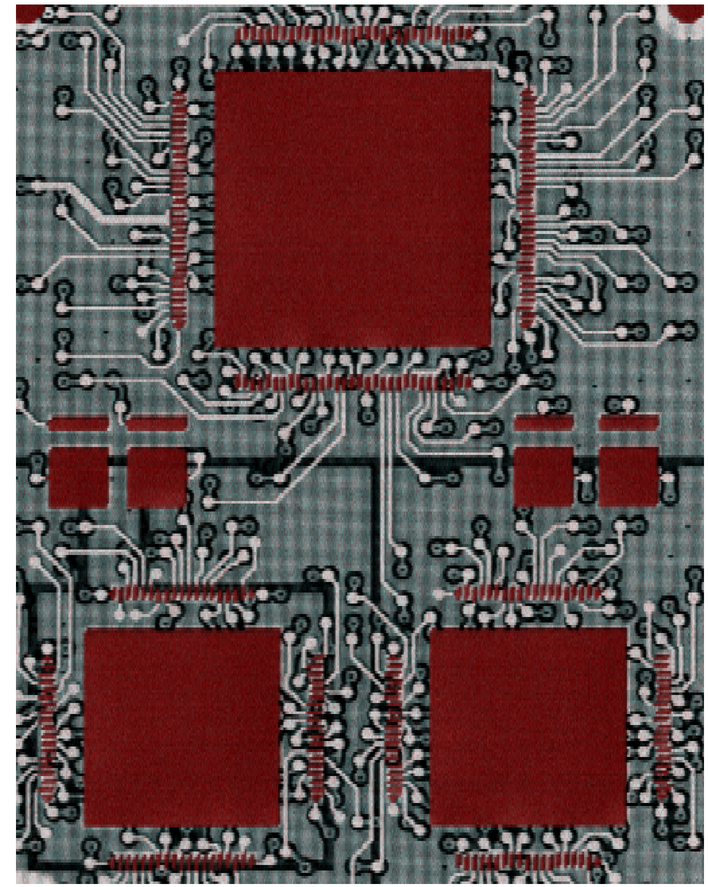
PCA/MCR even sorts filtered and unfiltered radiation such as Ni-filtered Cu Kα wavelengths

Two ***distinct*** components were observed for Cu emission lines:

- Kα emission only spectrum (red)
- another dominated by Kβ (cyan)

- The spatial map shows regions where the Cu Kα only is dominant (i.e. red blocks).
- Since red + cyan = white, the white circuit traces indicate a *combination* of the two components (i.e. unfiltered Cu spectrum).





The presence of Ni layer over the Cu circuitry renders these areas red.

Summary

- μ-XRF coupled with Principal Component Analysis can prove very helpful for detection of weak XRF signals.
- Simultaneous PCA on multiple circuit board datasets aided in detection of defects in sandwiched Pd metal layers.
- Filtering effects (e.g. Ni on Cu) can be diagnosed via separate components within PCA.

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