Endpoint Detection of Low Open Area Contact Etches from Optical Emission Spectroscopy Measurements

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AEC/APC 2000

Agenda

- Goals of the project
- Hardware and data collection methods
- Calibration of the analysis algorithm
- Endpoint results on graded % open area contacts
- Conclusion

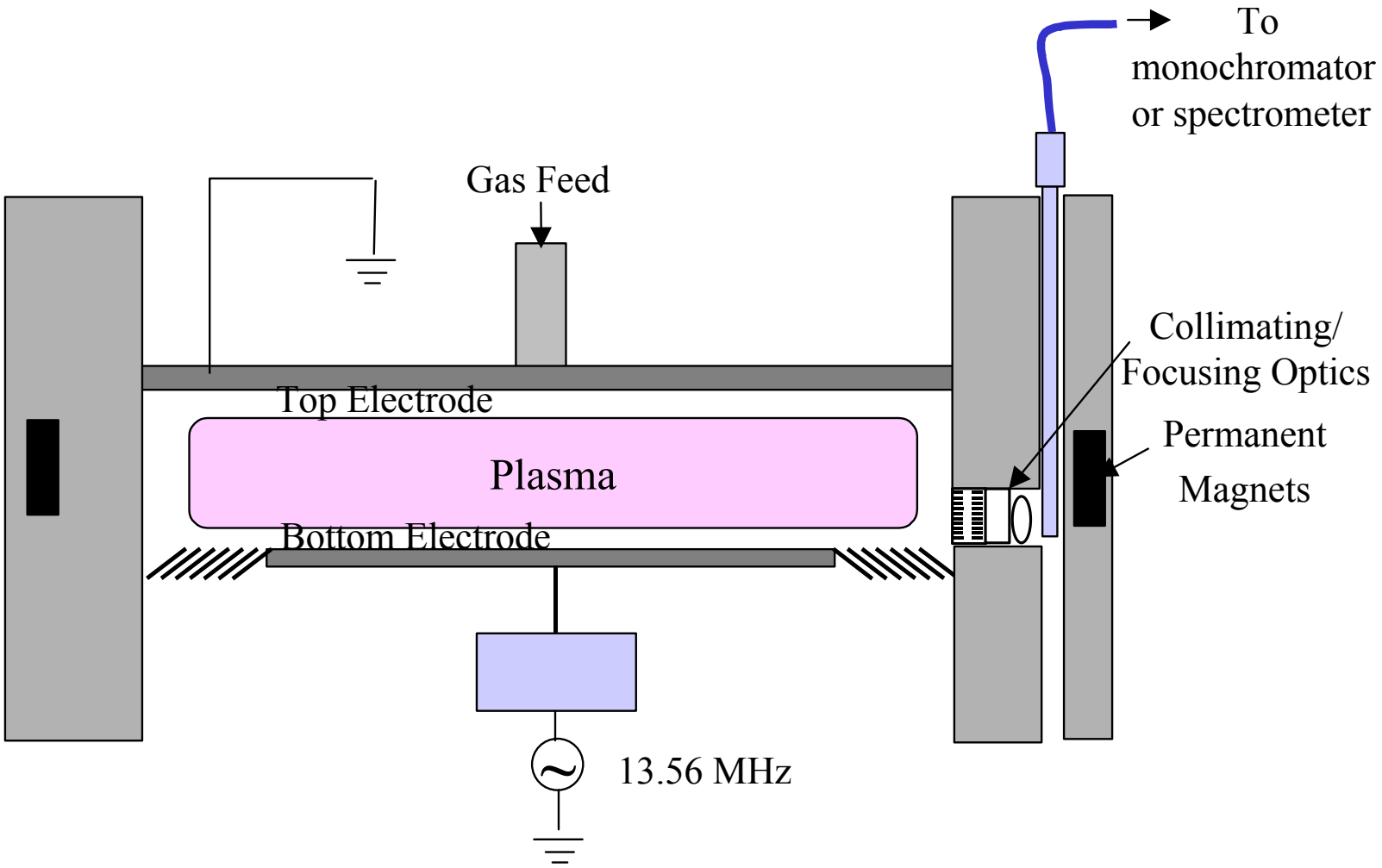
Projects Goals

- Demonstrate OES endpoint on low open area contact etch
- Accommodate plasma spectral intensity modulation caused by rotating magnetic fields
- Develop an endpoint detection algorithm that shortens the time and spectroscopy expertise that is required for a new etch process

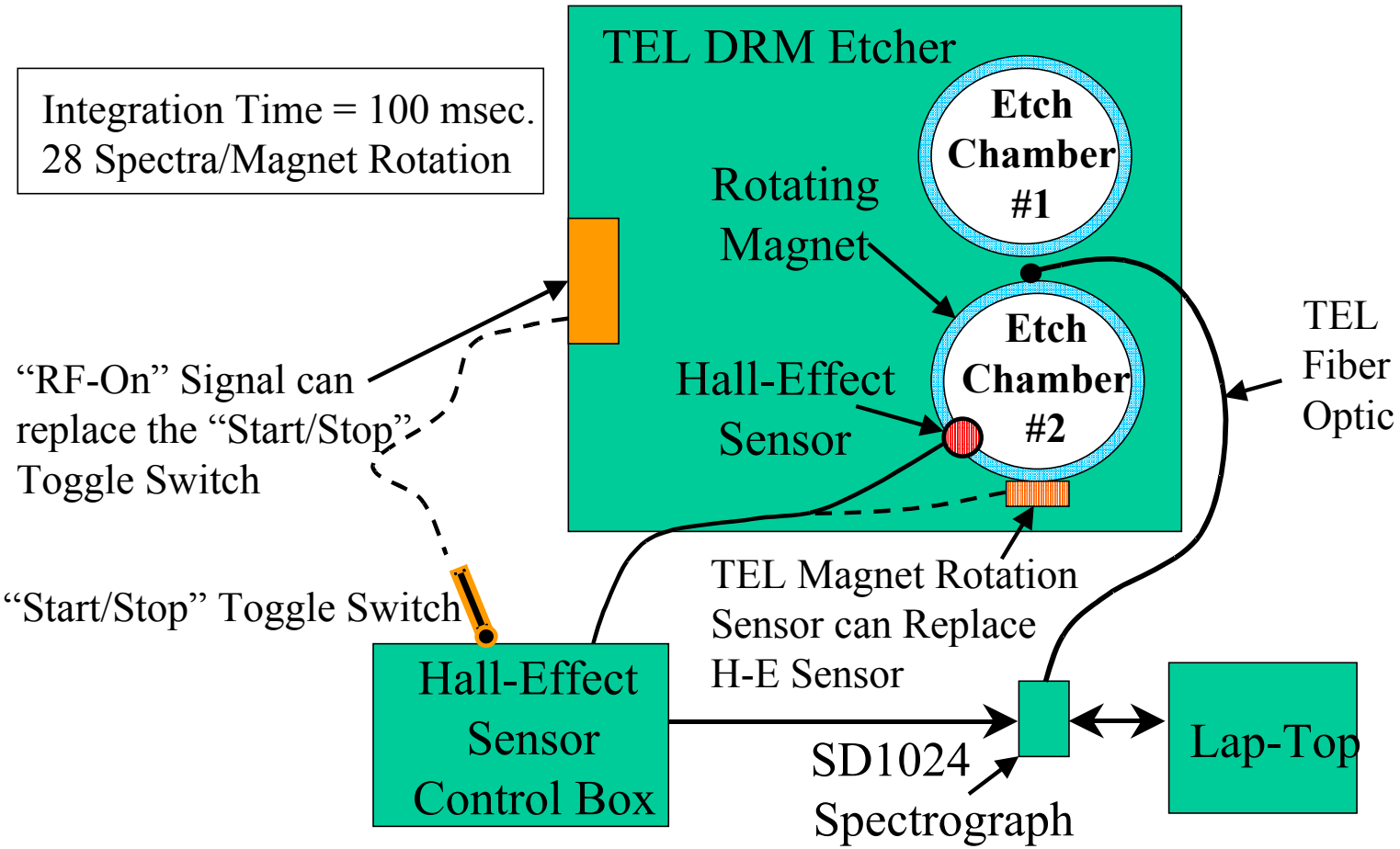
Approach

- Use a spectrograph to measure plasma light intensities (200-800 nm)
- Synchronize the data collection with the rotating magnet
- Apply multivariate analysis methods to take full advantage of the wealth of spectral data

TEL DRM Etcher



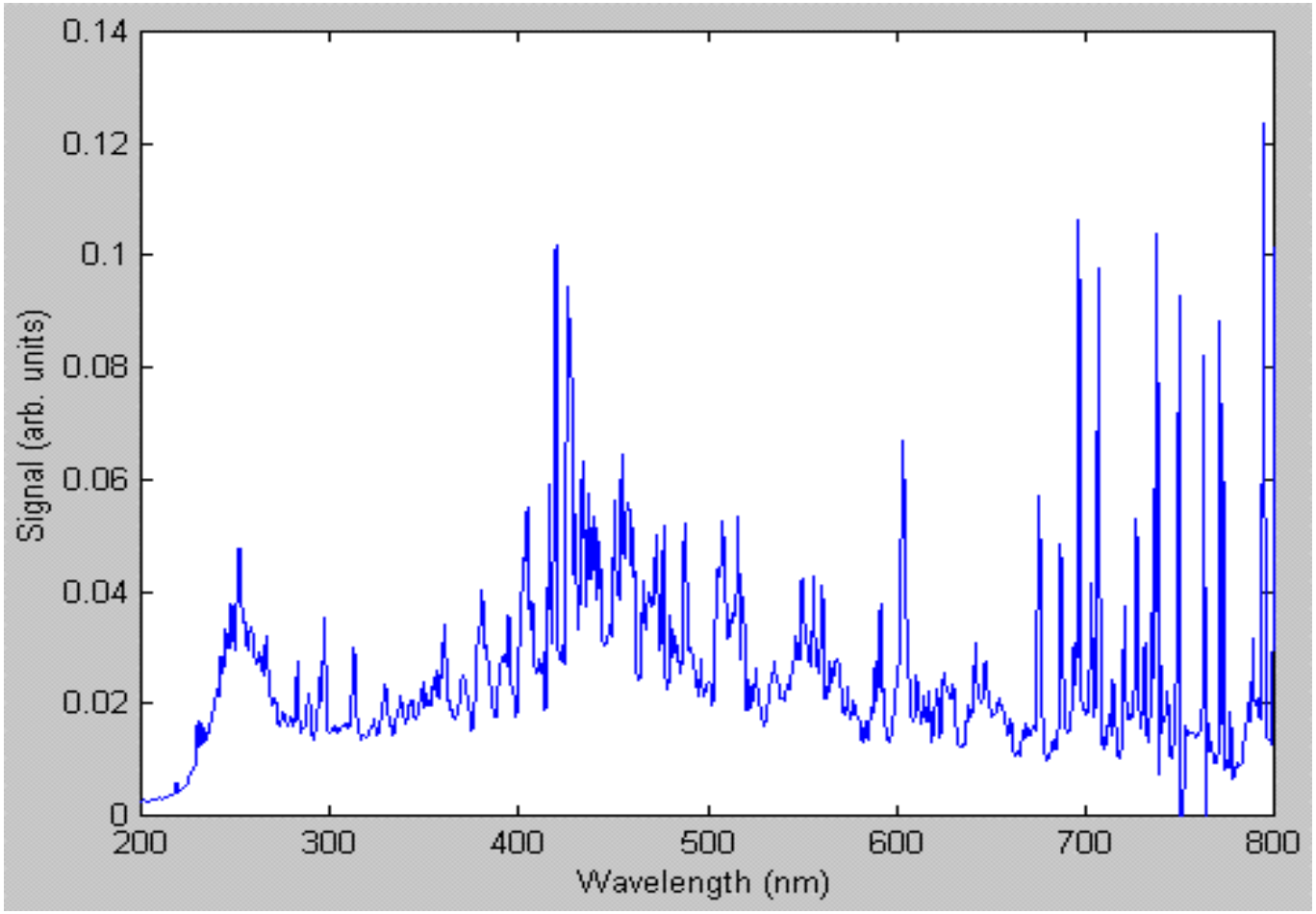
Synchronized Data Collection



Spectrograph

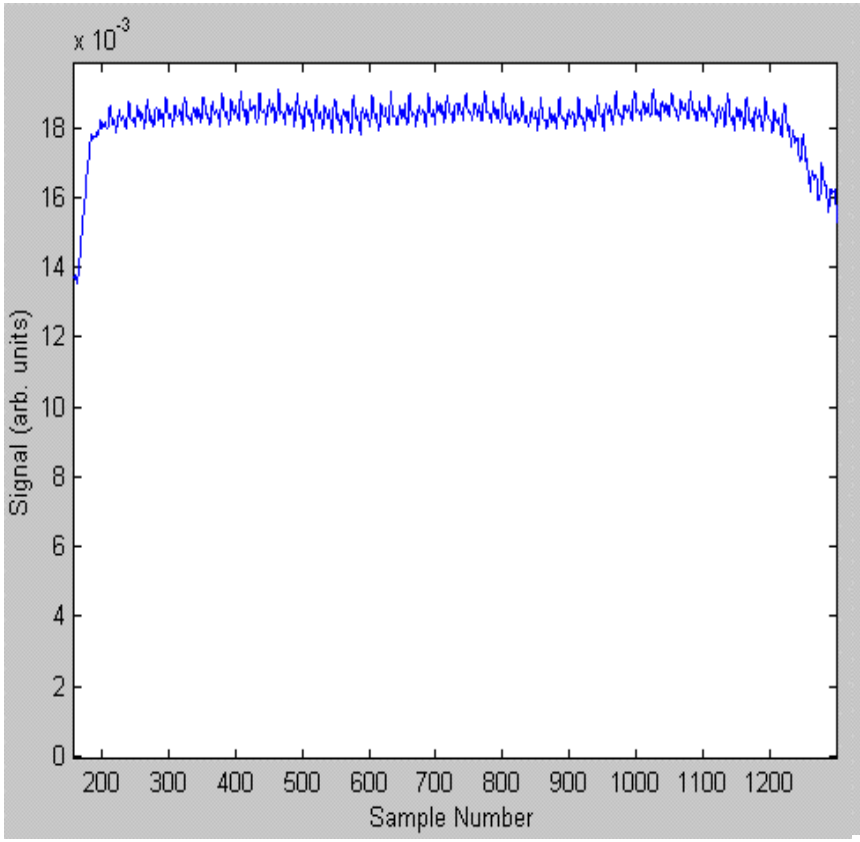
- Optics
  - 200 – 800 nm coverage
  - TE cooled 2D imaging
    - Acquires multiple spectra simultaneously
    - Wide dynamic range (65000:1) and low noise
- Embedded processor
  - Calibration
  - Spectra reported at even half-integral wavelengths
- Signal processing software

Plasma Spectrum

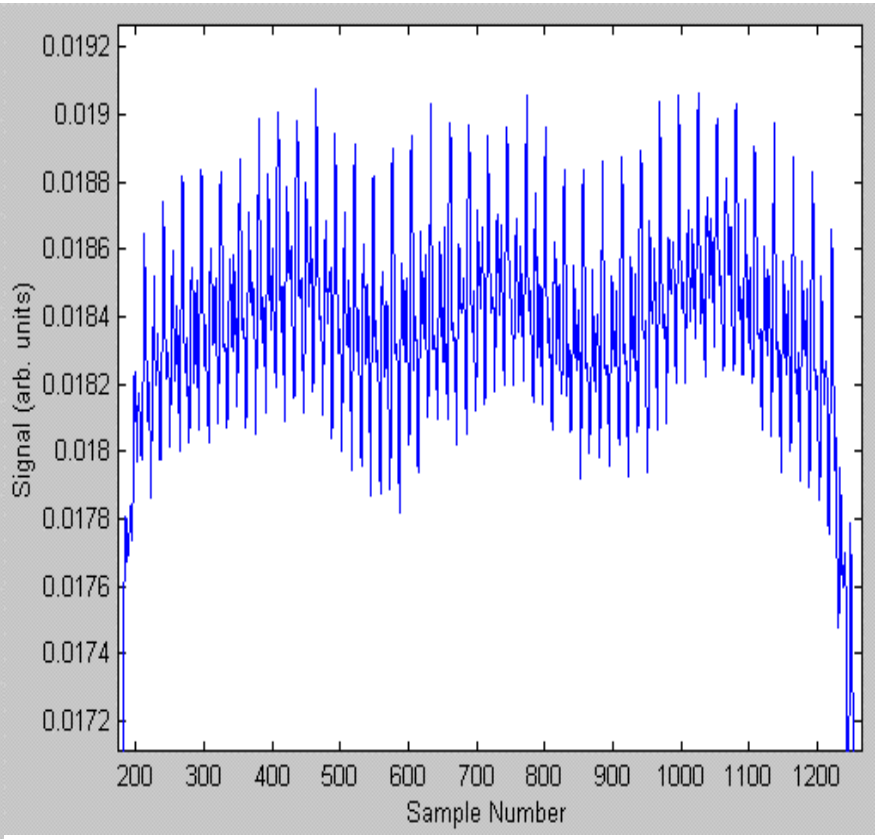


Typical Measured Spectrum

Plasma Spectrum

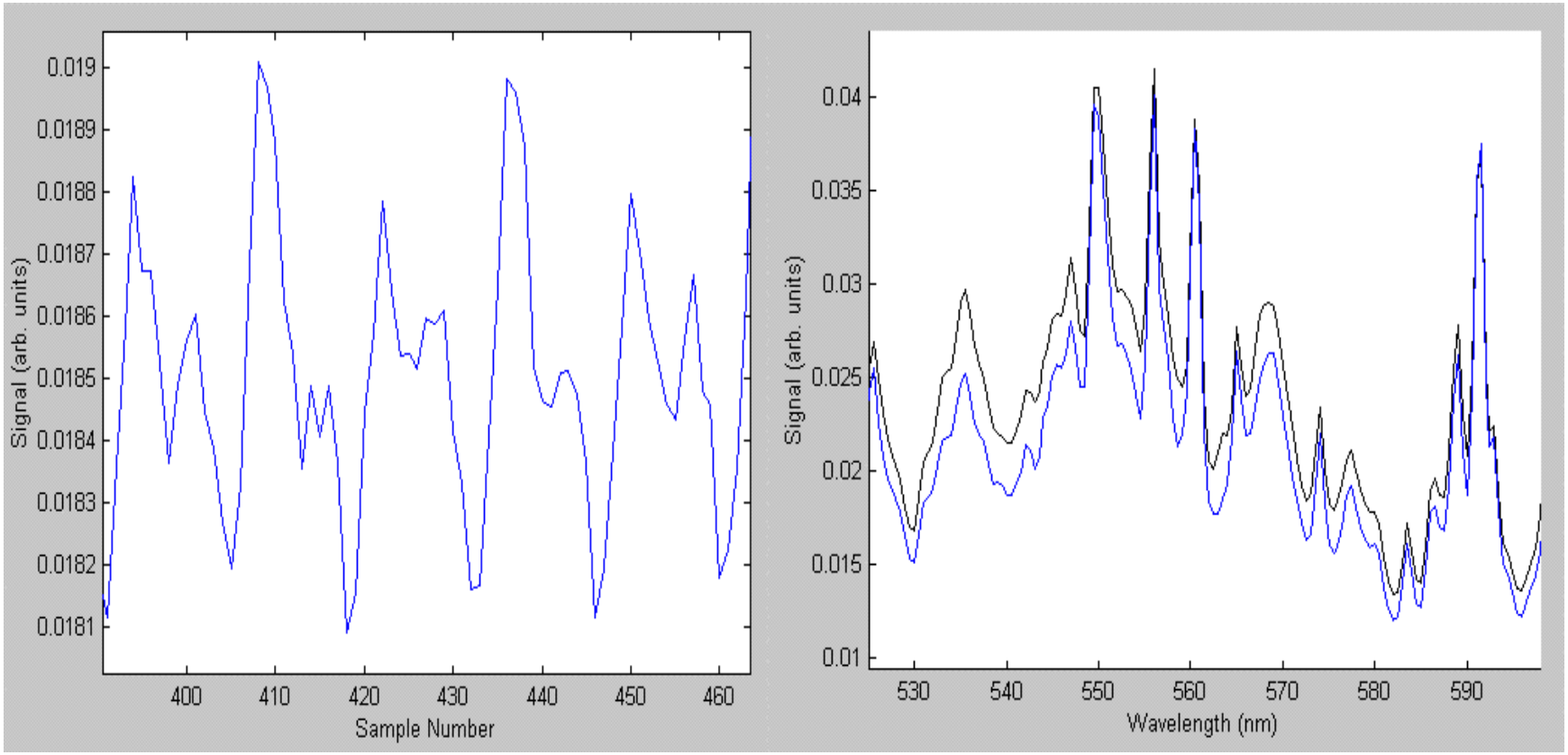


Time variation of signal at 325 nm



Close up

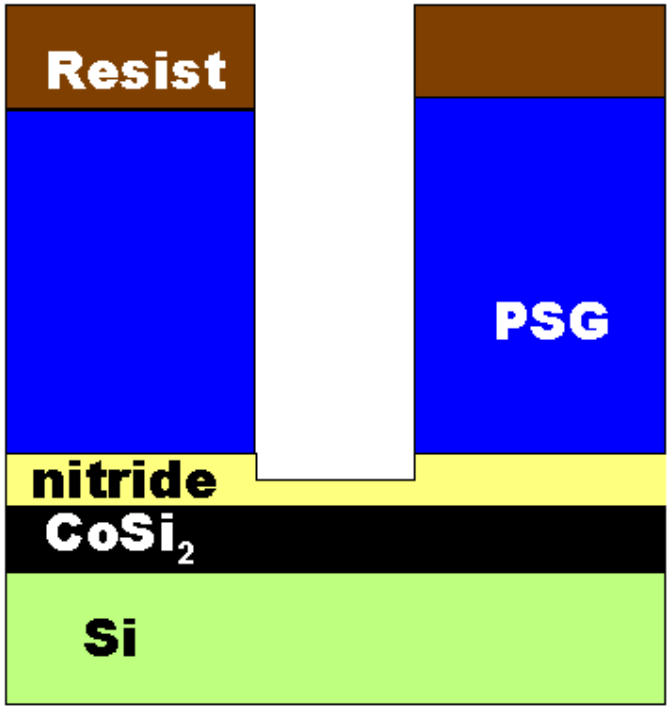
Plasma Spectrum



Time variation of signal at 325 nm

Variation of spectrum,
at Sample 409 and 419

Wafer Structures

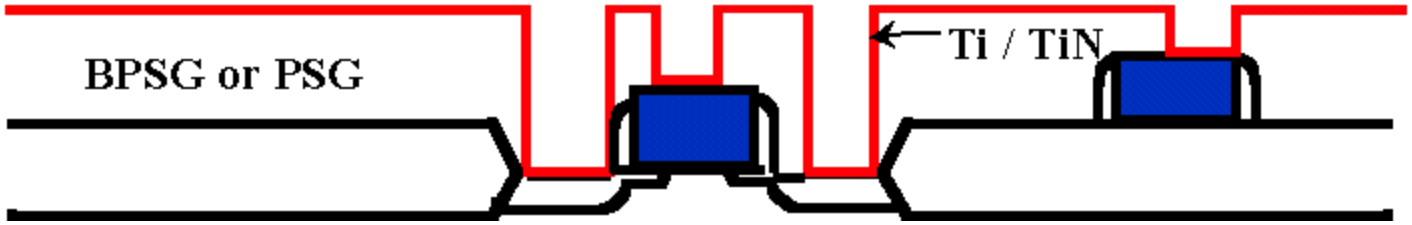


Old Technology

New Technology

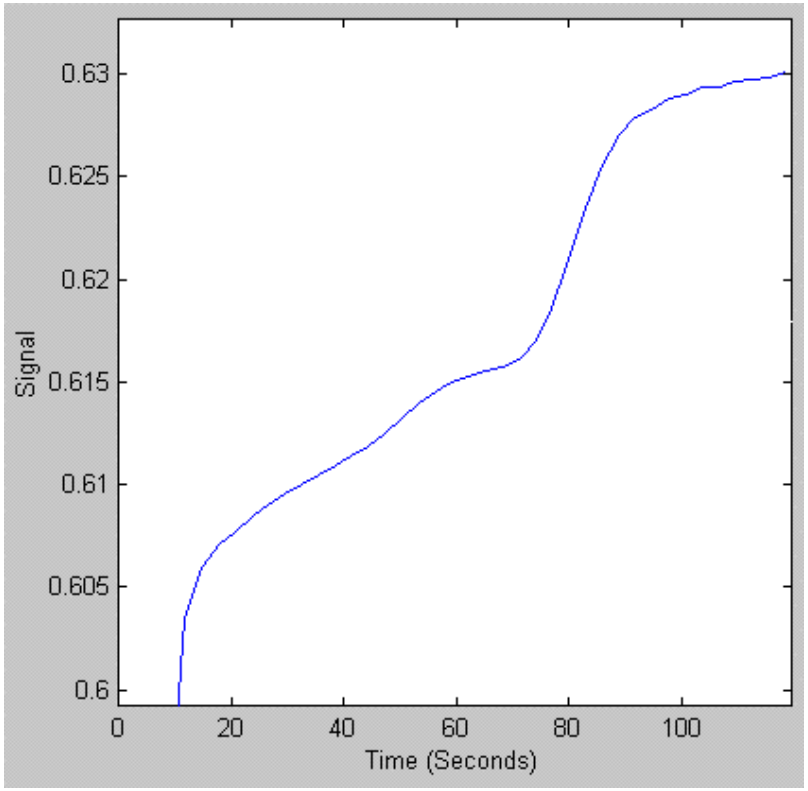
Etched with CO, CH_2F_2, O_2, and Ar chemistry

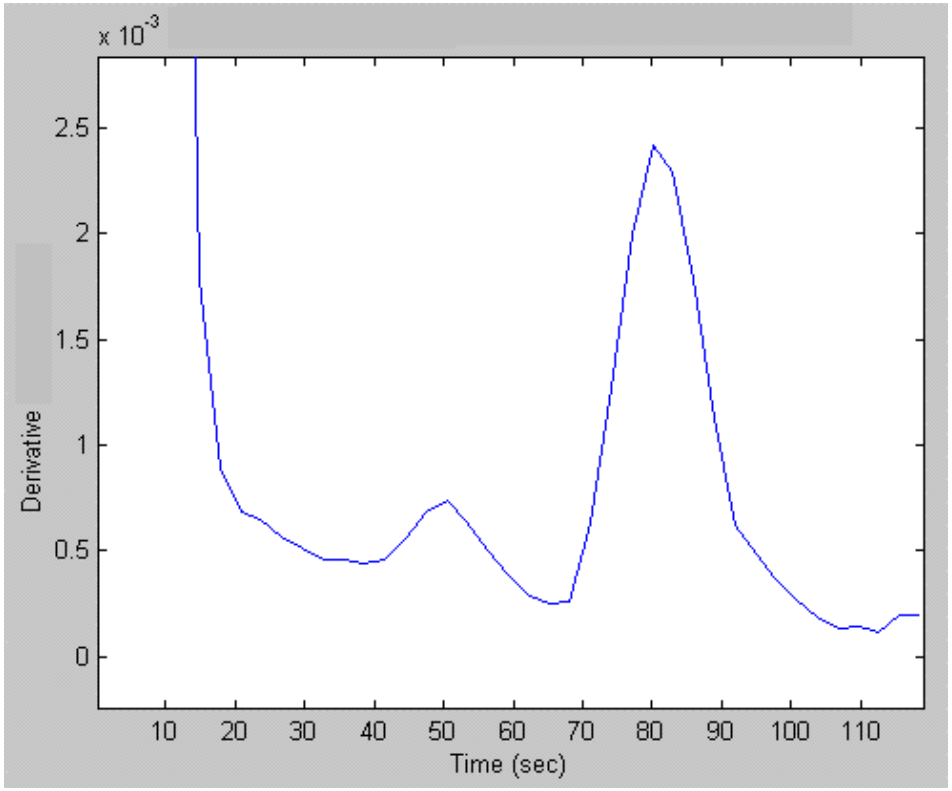
Topology



Topology allows different depths over S/D and gate contacts

End Point Signal

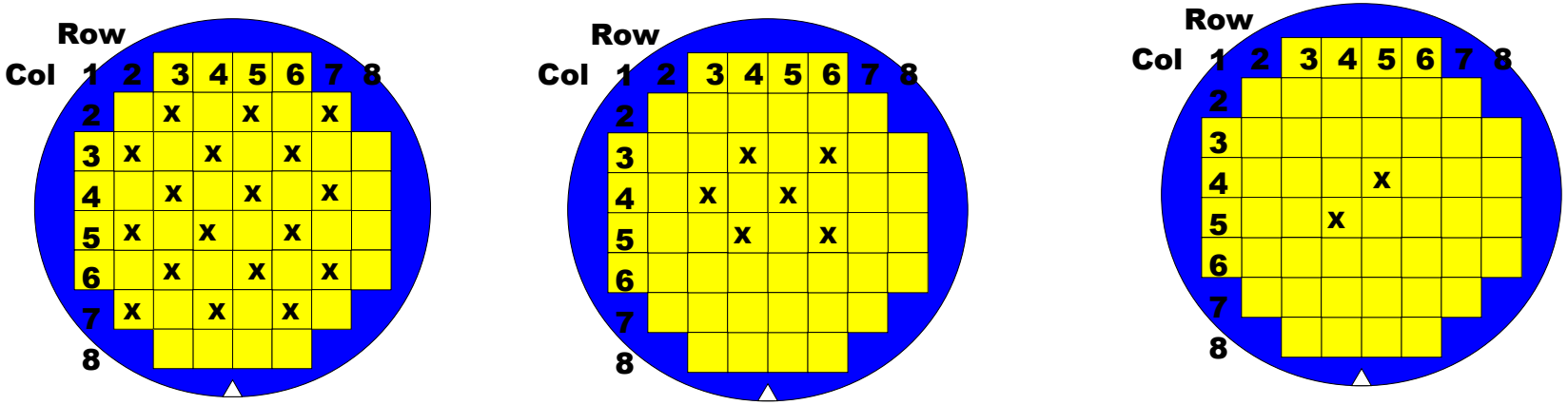




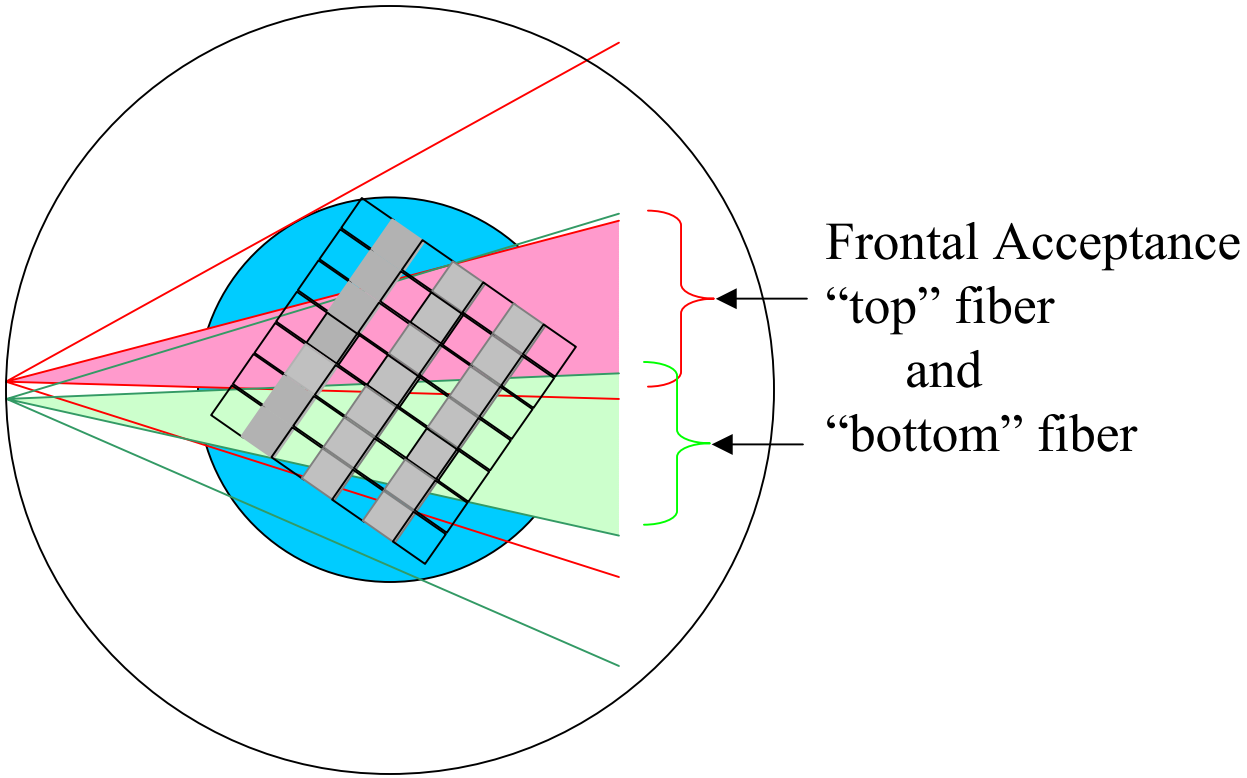
Endpoint signal for 4 % open area contact etch
of a production wafer using Neural PCA

Graded Die layouts

	13	14	15	16	17	18	19	20	21	22	23	24	
52 die (1.32 % open area)	X	X	X	X									expose all die
18 die (0.45 % open area)					X	X	X						expose every third die
6 die (0.15 % open area)								X	X	X			3 in row above center; 3 in row below center;
2 die (0.05 % open area)											X	X	1 above center; 1 below center

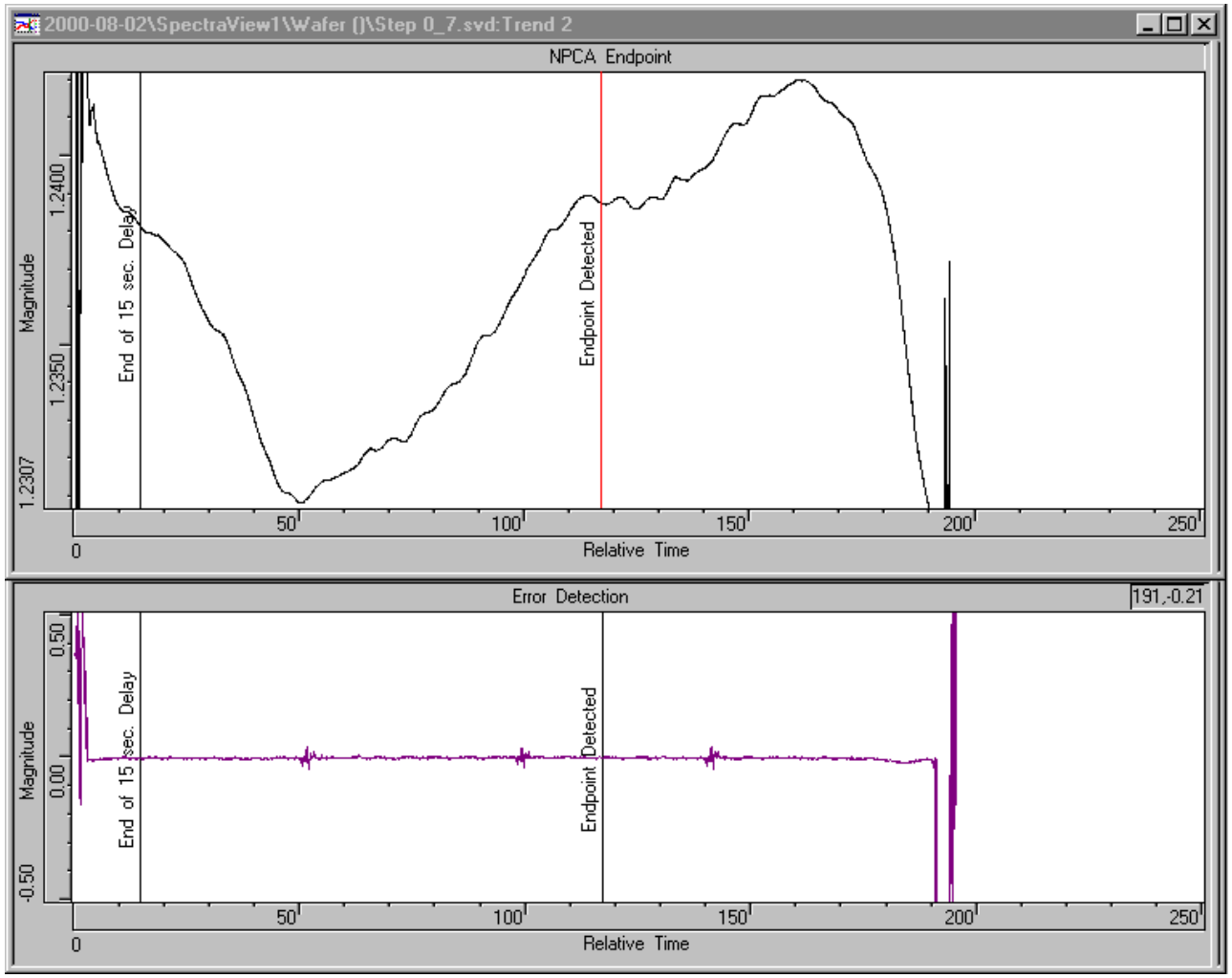


Acceptance angle



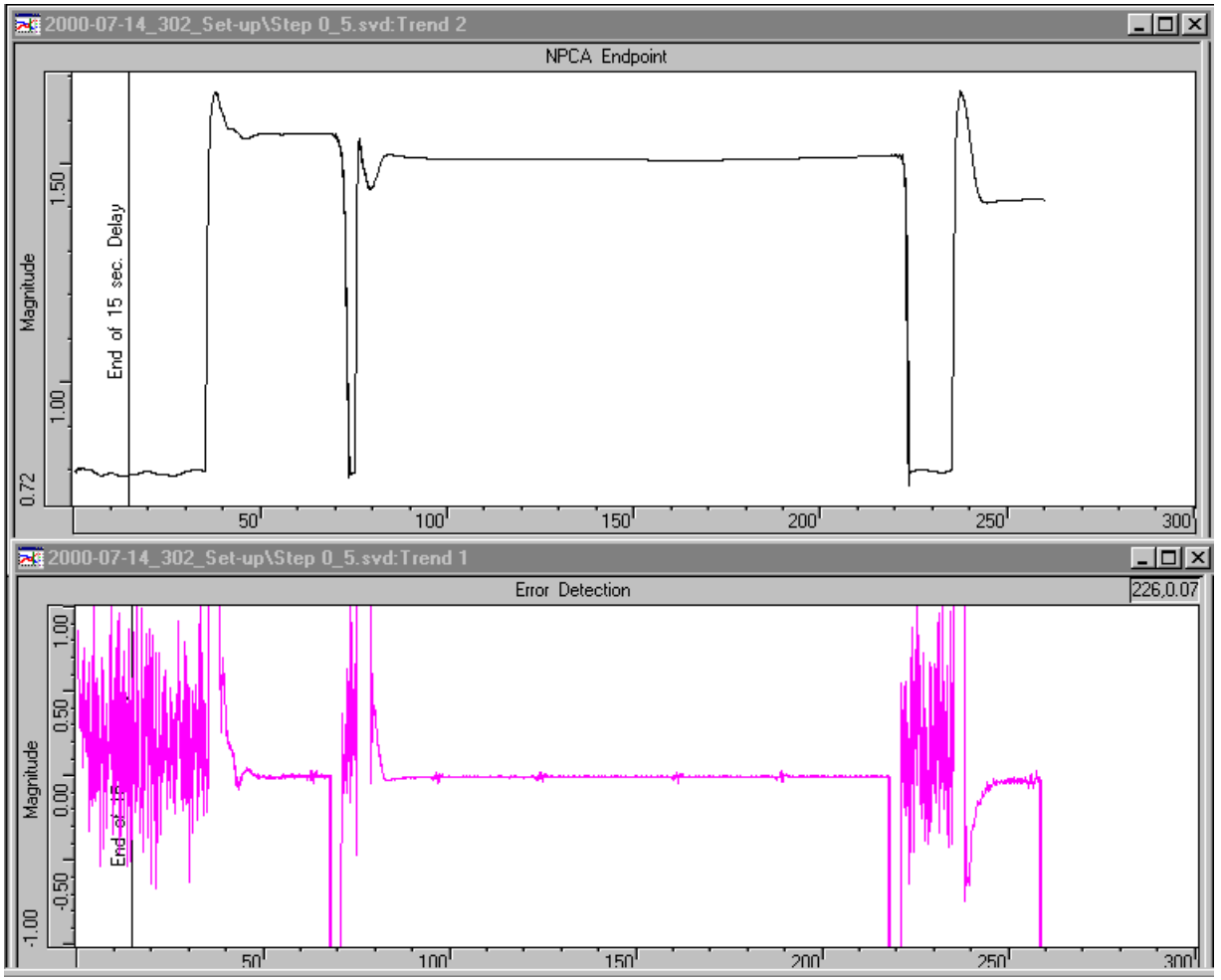
The measured acceptance angle of the TEL fiber optic is shown. The fiber optic is located 200 mm from the wafer center.

Endpoint Signal



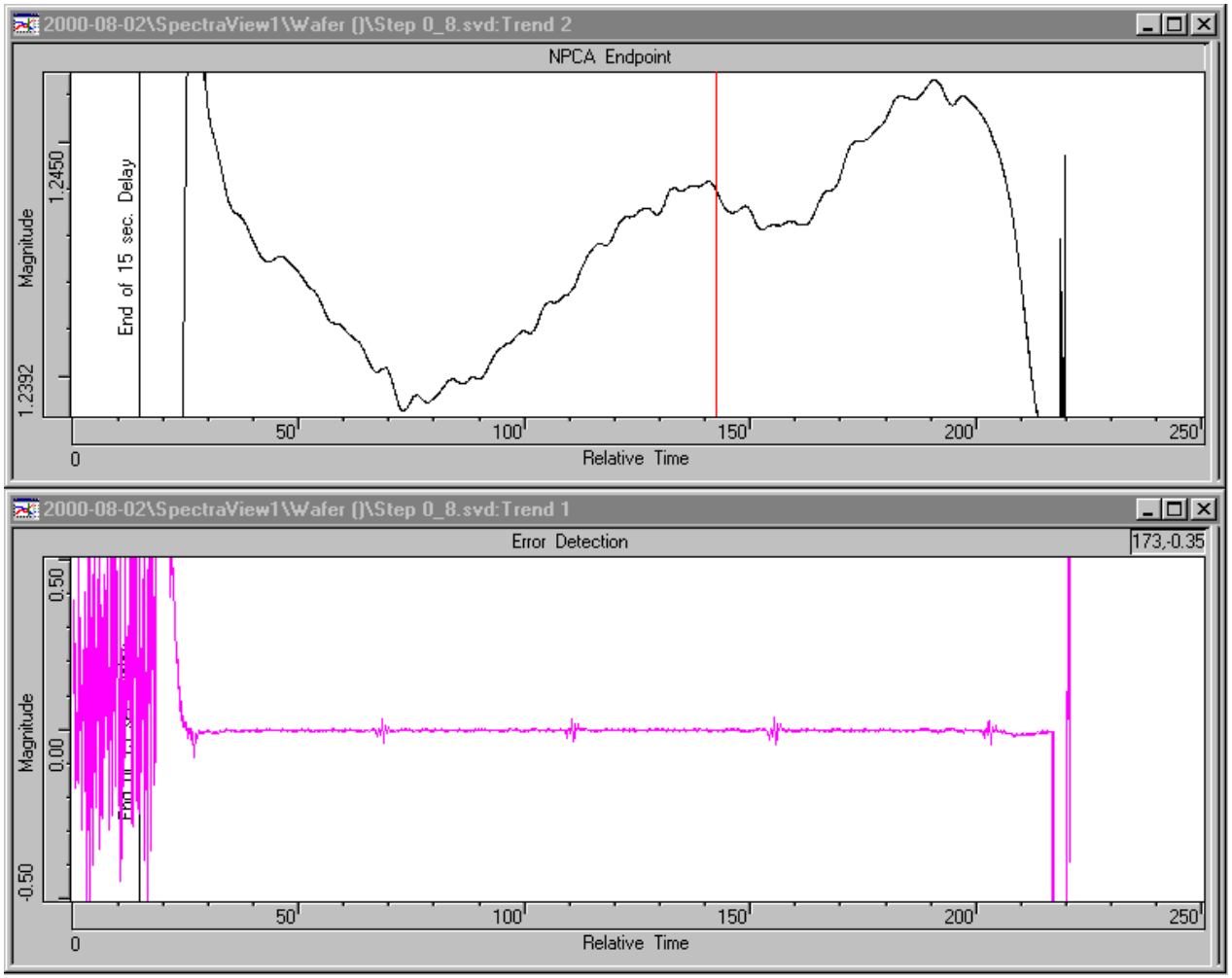
Endpoint Signal for 1.3% Open Area Contacts (52 Die)

Error Detection Algorithm



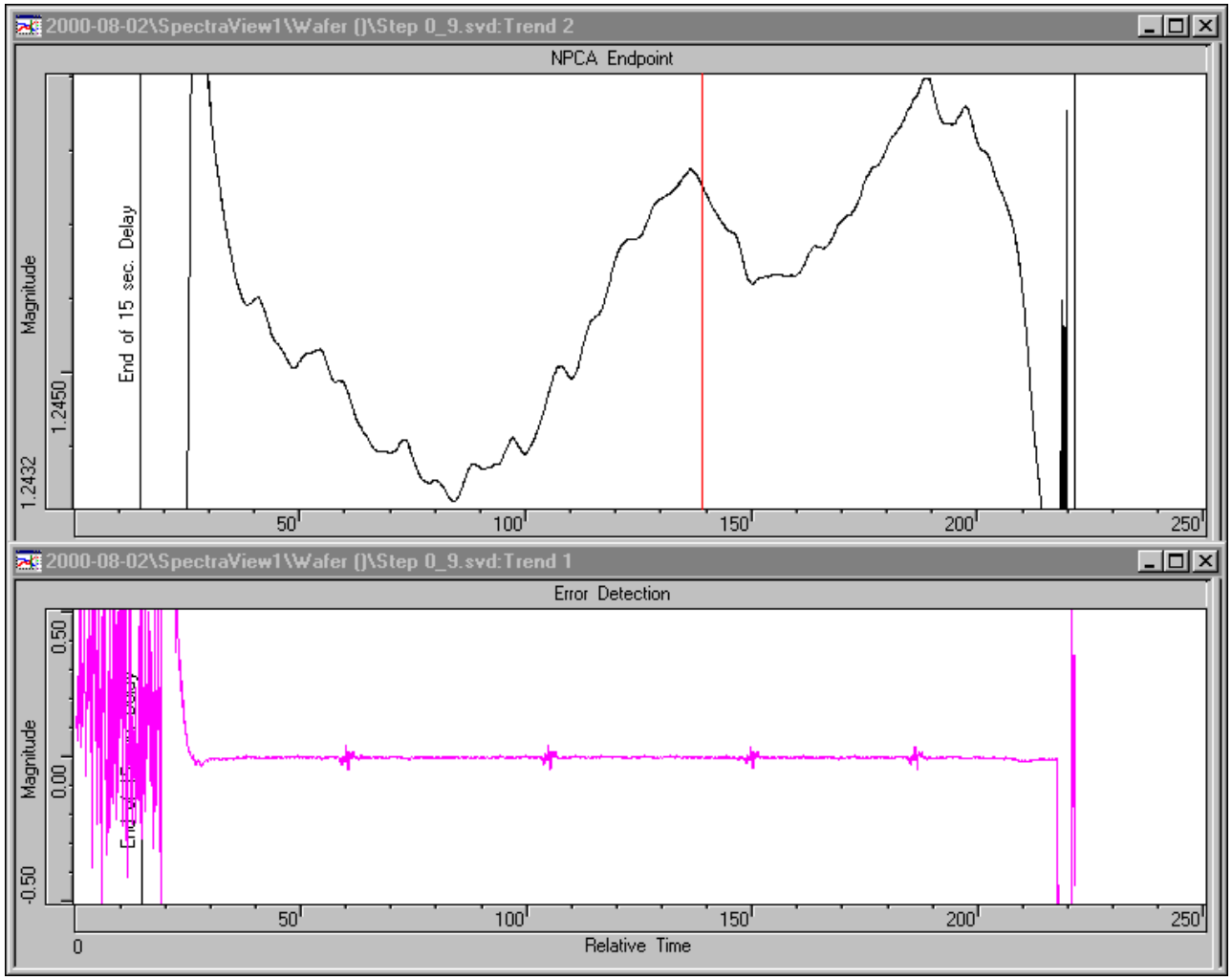
The Error Detection Algorithm monitors the TEL etcher “plasma leak.”

Endpoint Signal



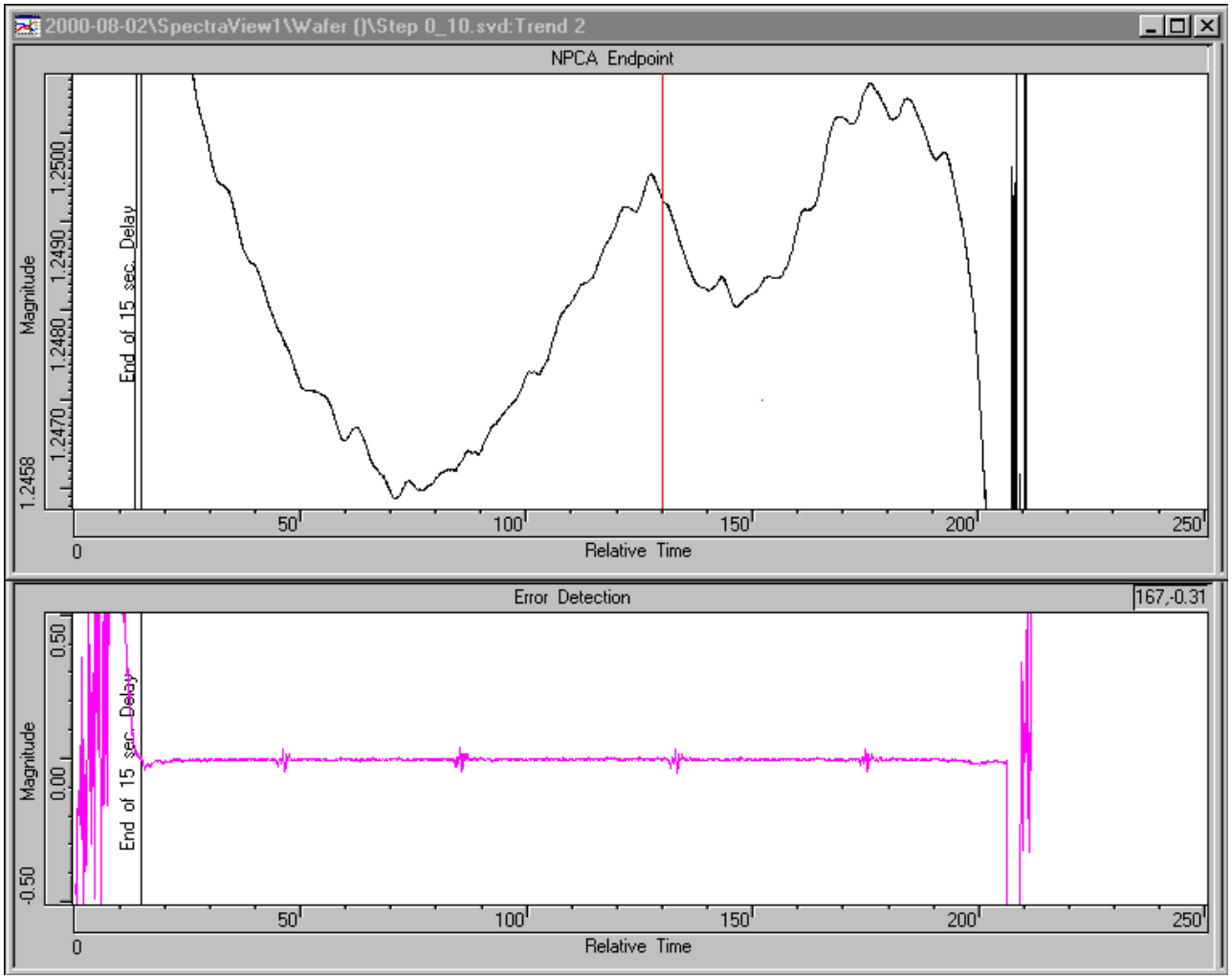
Endpoint Signal for 0.45 % Open Area Contacts (18 Die)

Endpoint Signal



Endpoint Signal for 0.15 % Open Area Contacts (6 Die)

Endpoint Signal

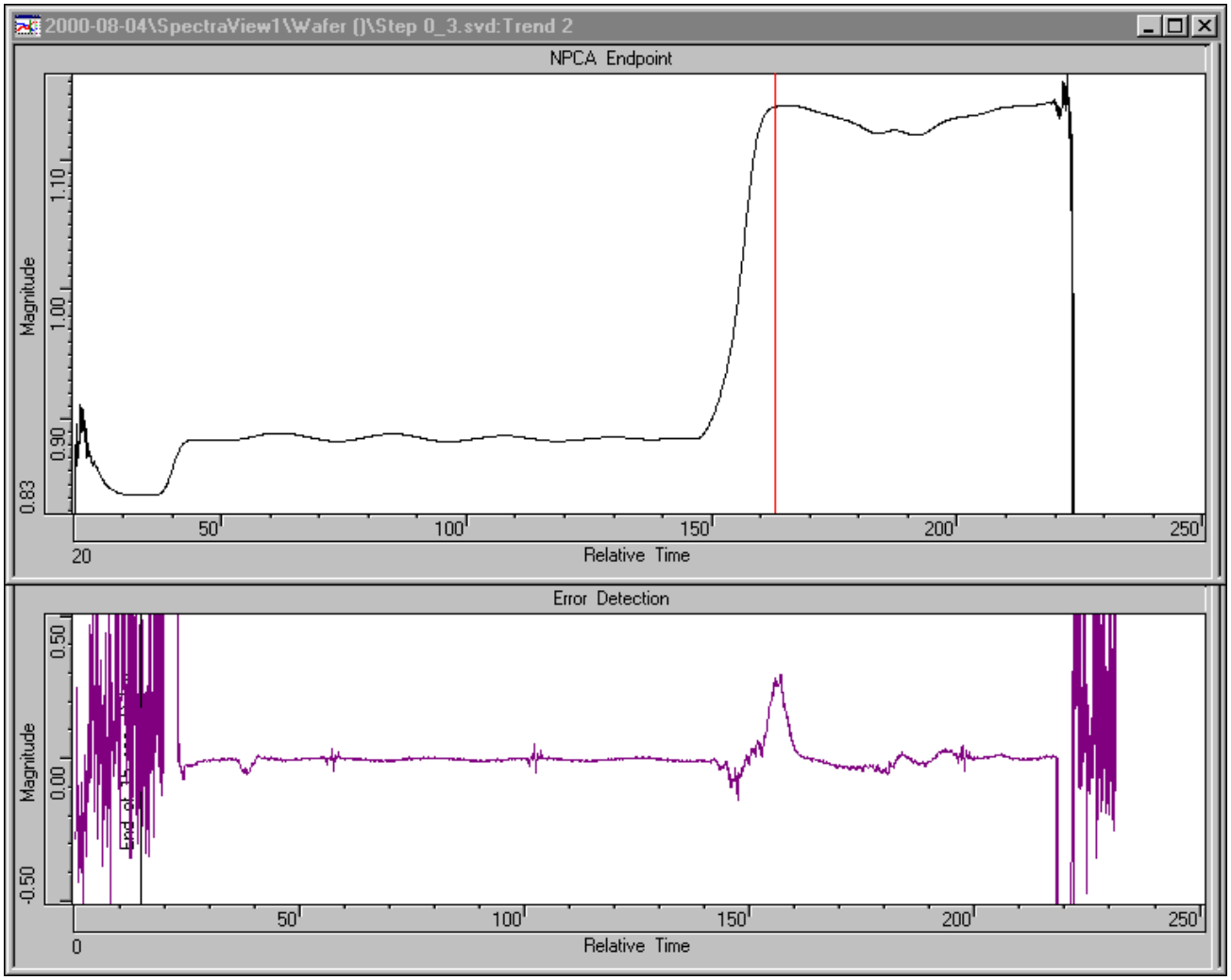


Endpoint Signal for 0.05 % Open Area Contacts (2 Die)

Endpoint Times

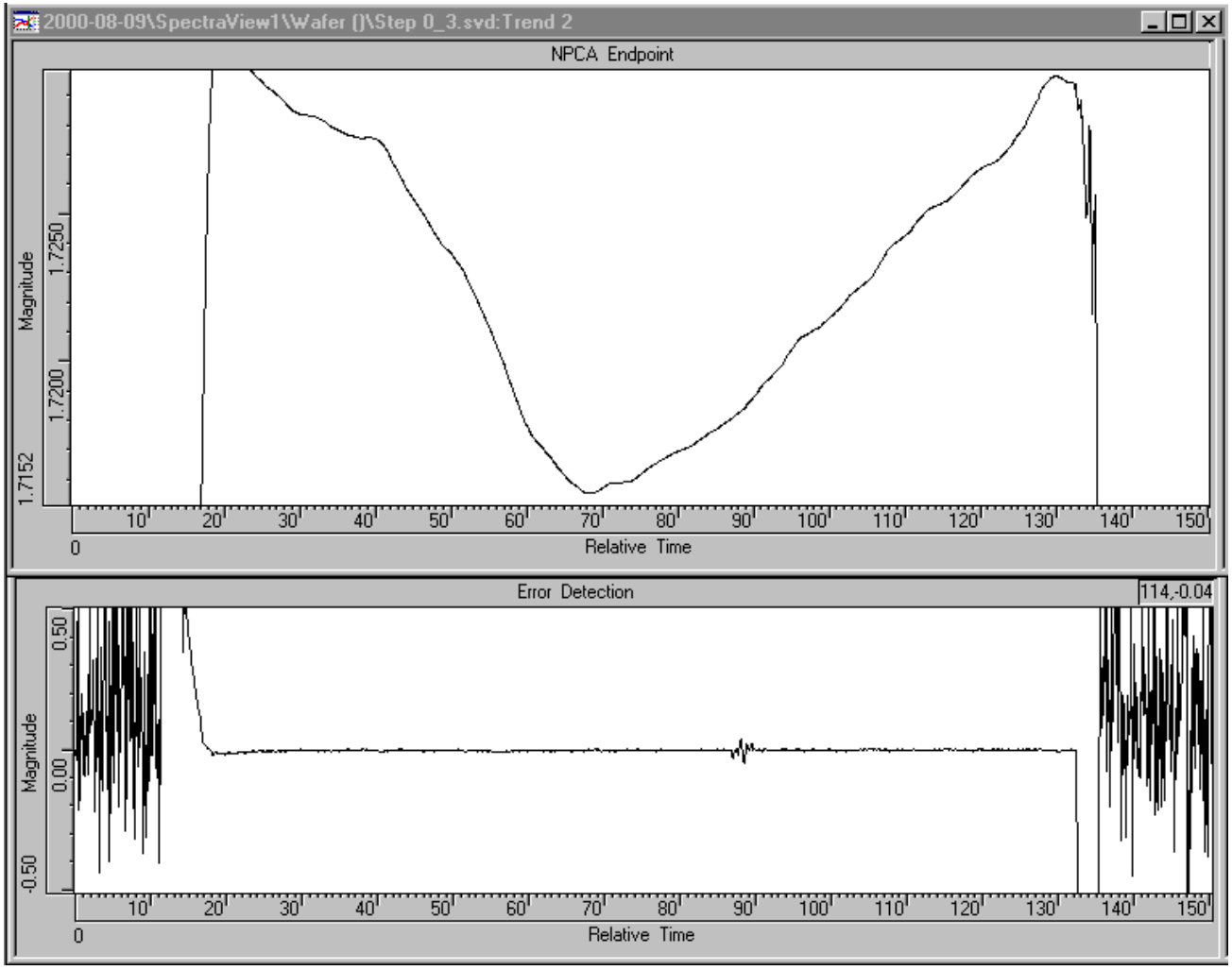
Wafer #	% Open Area	Endpoint (sec.)
13	1.3	124
17	0.4	126
20	0.1	121
23	0.05	124

Endpoint Trace



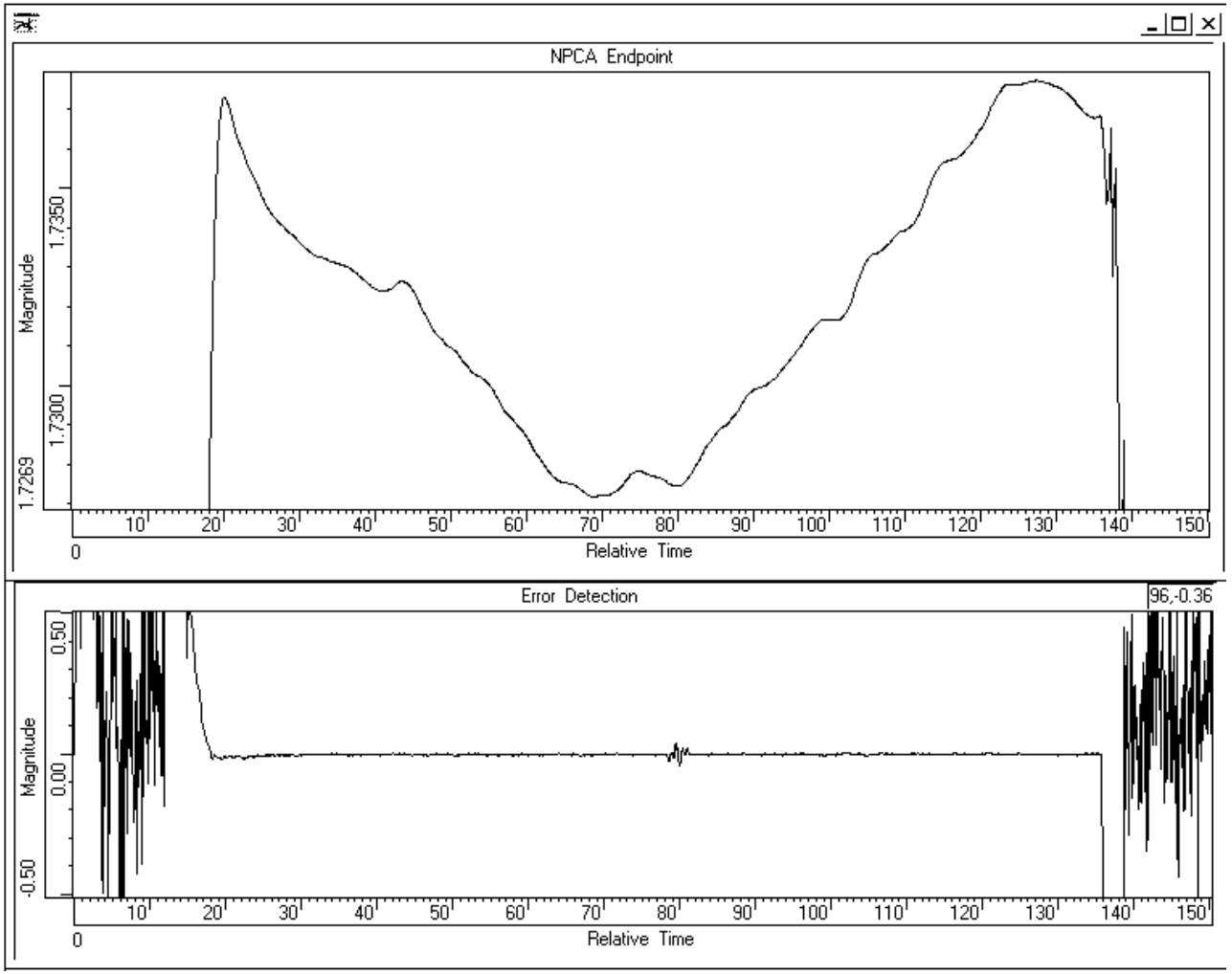
Endpoint Trace for 100% Open Area Contacts (blanket wafer)

Endpoint Signal



Endpoint Call for 1.32 % Open Area Contacts (52 Die)

Endpoint Signal



Endpoint Call for 0.45 % Open Area Contacts (18 Die)

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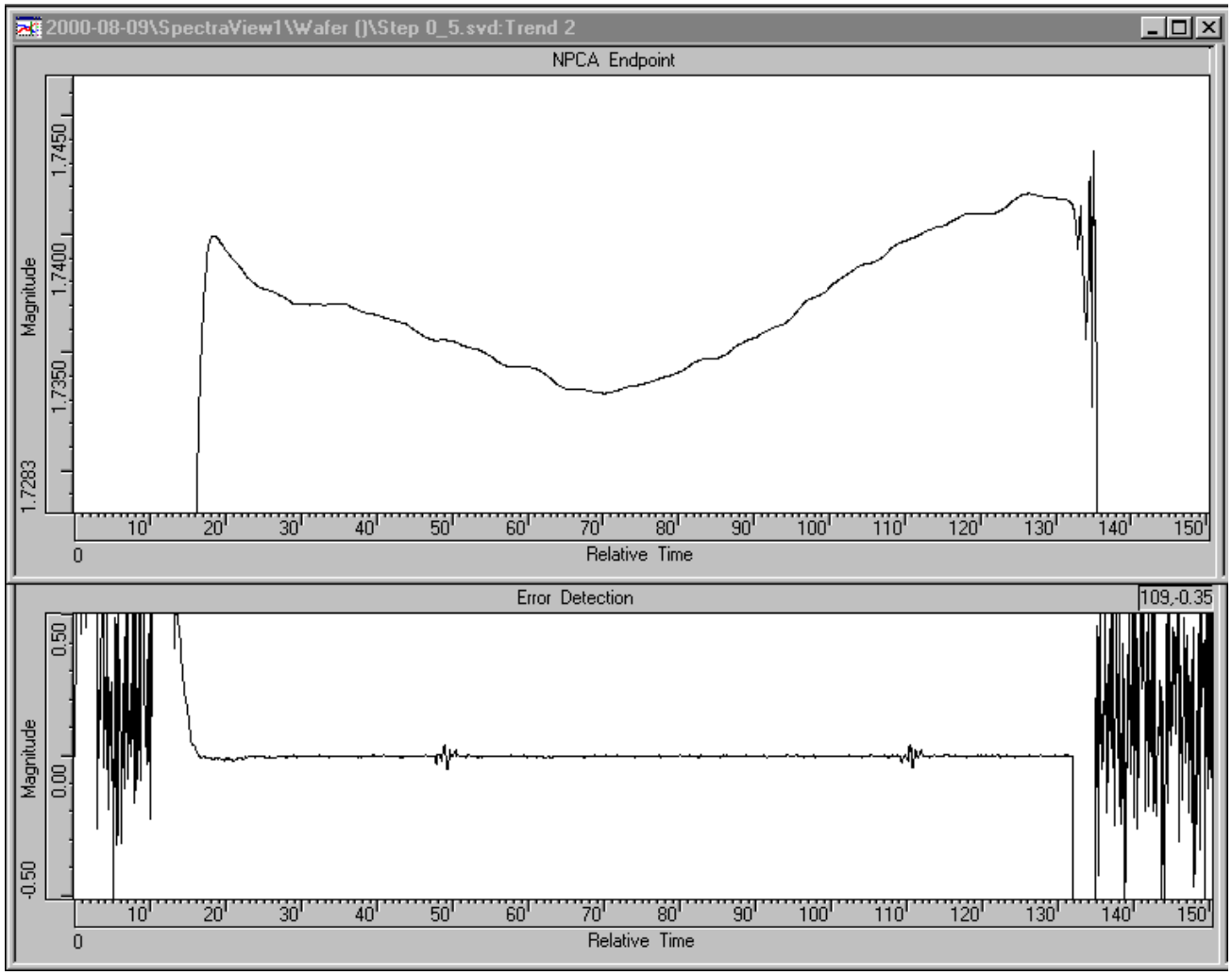
Endpoint Signal



Endpoint Call for 0.15 % Open Area Contacts (6 Die)

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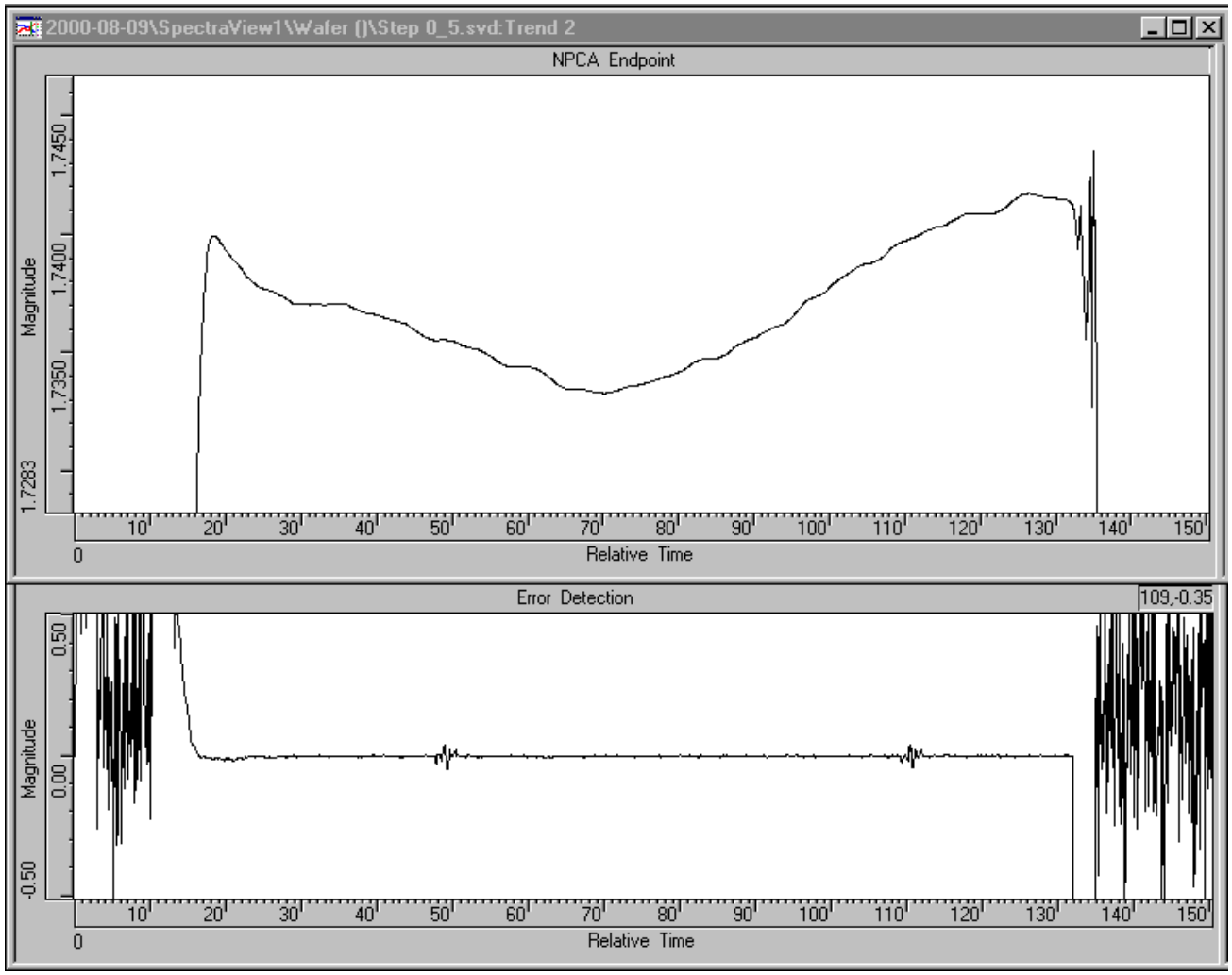
Endpoint Signal



Endpoint Call for 0.05 % Open Area Contacts (2 Die)

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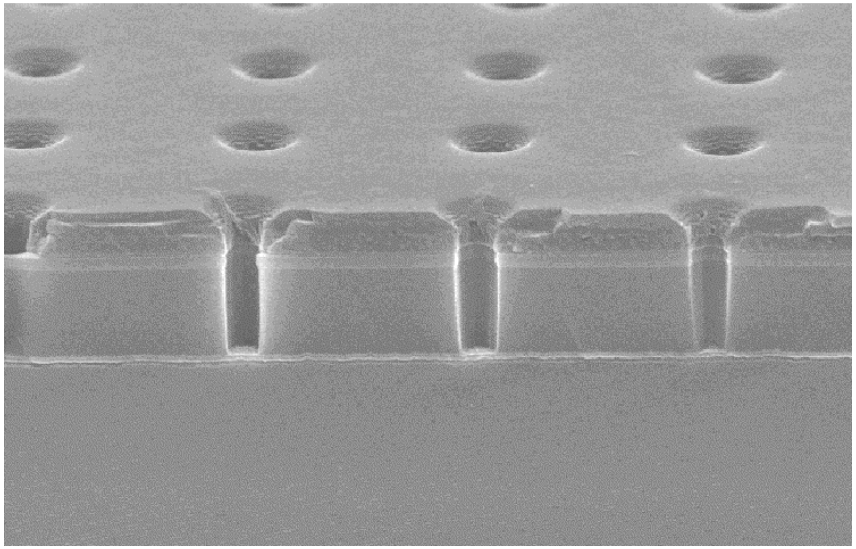
Endpoint Call Times

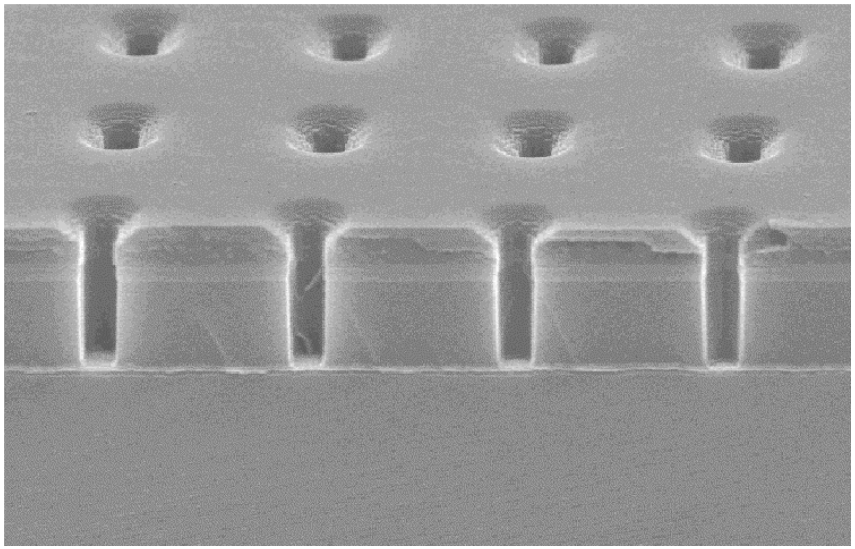
Wafer #	% Open Area	Endpoint (sec.)
15	1.3	121
18	0.4	124
21	0.1	122
24	0.05	122

X-SEM Results

Square contacts



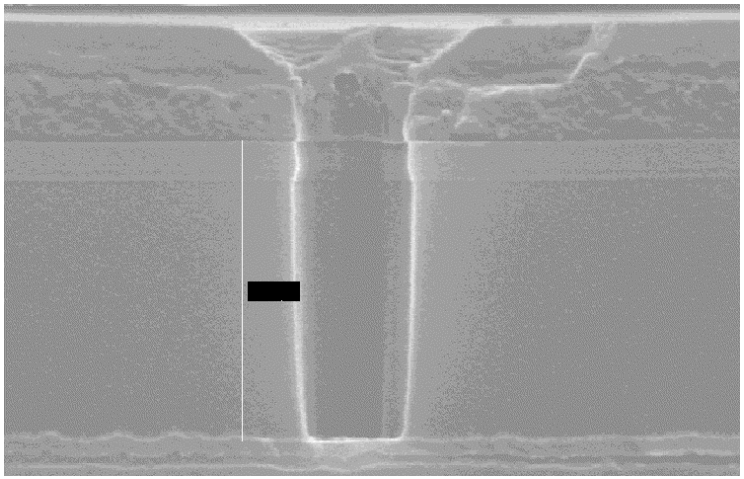
Rectangular contacts

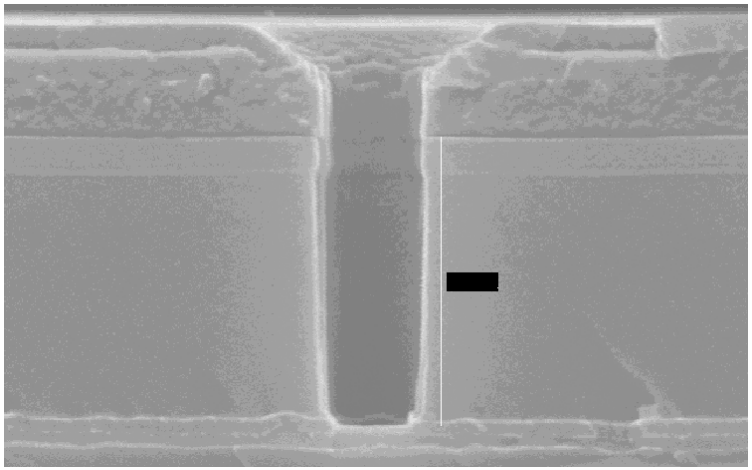


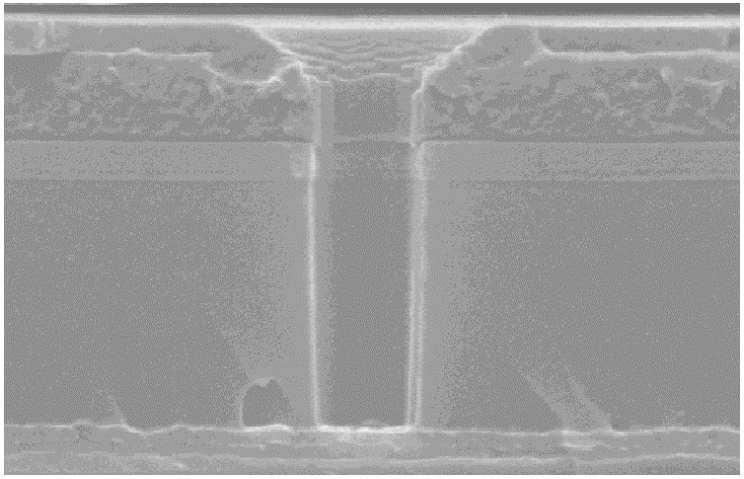
X-SEM Results

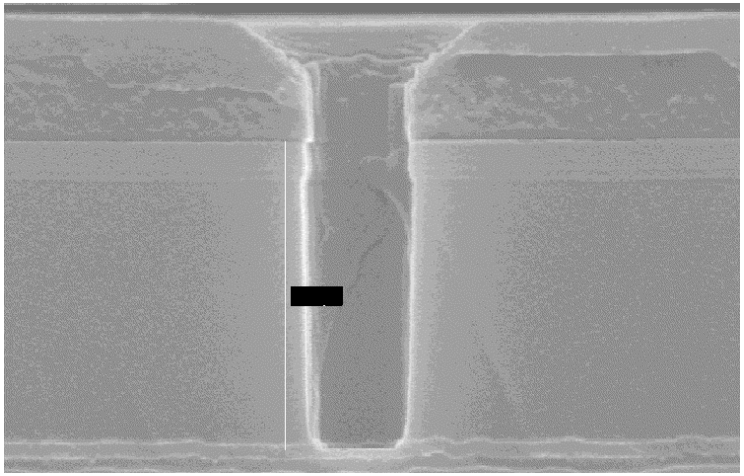
Square contacts

Rectangular contacts









Summary

- Contact etch endpoint can be detected well below 0.1 % open area with OES.
- Plasma spectral intensity modulation can be accommodated by synchronizing data collection with magnet rotation.
- Multivariate analysis takes advantage of the wealth of data from the spectrograph to enhance the endpoint signal-to-noise.