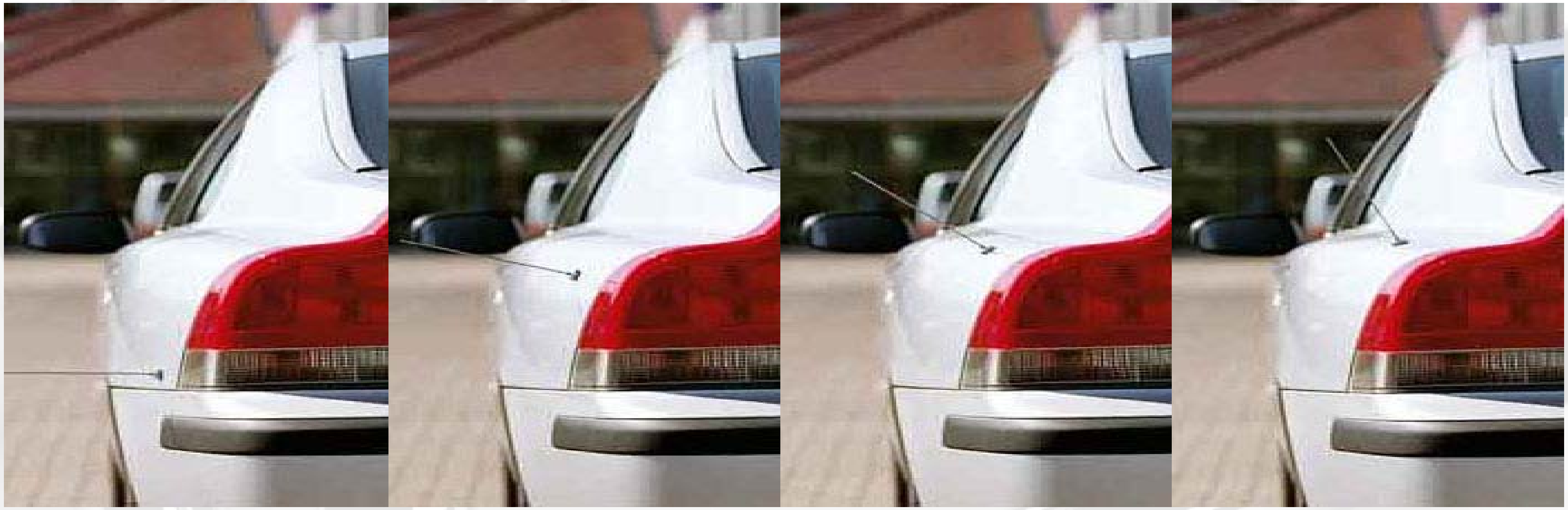
American Coatings Conference
June 5, 2008
Jon Nisper

xDNA™

x·rite

Visual vs. Instrumental

- Existing instrumental assessments for effect colors are based on direct illumination and observation in plane.



- A car body has more geometries out of plane than in plane.

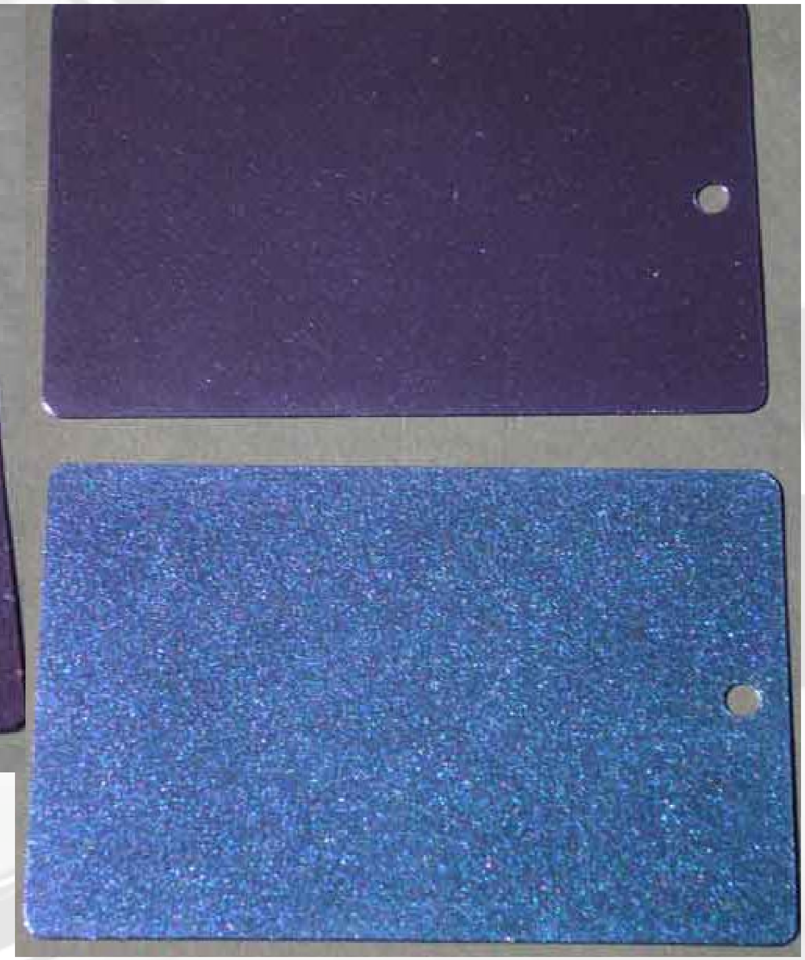
In-plane spectrophotometry is insufficient

45° illumination, different viewing angles

Left:
ChromaFlair 190

Right:
Viola Fantasy + Blue

45° illumination, out of plane viewing

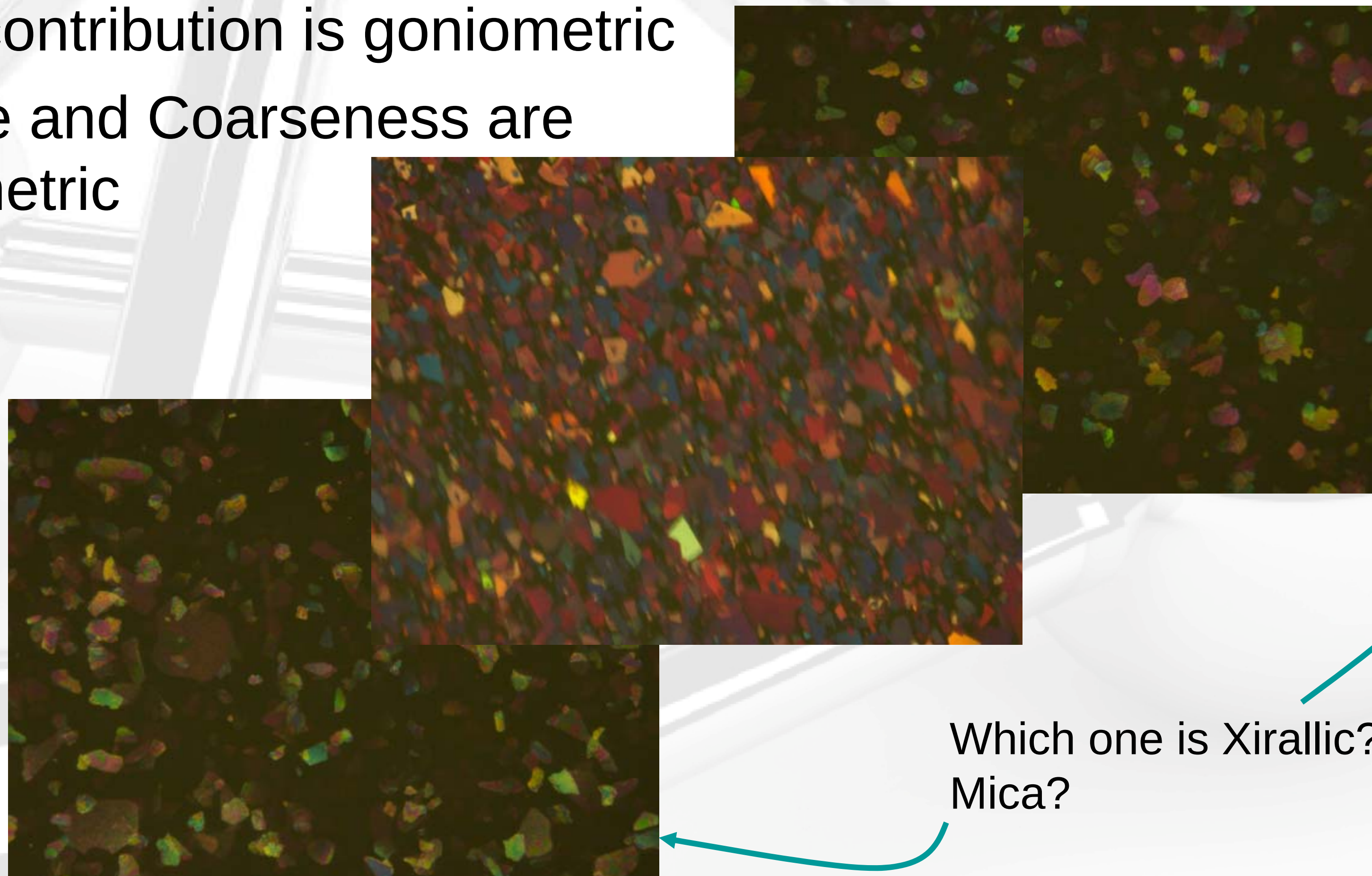


Top: Viola Fantasy + Blue

Bottom: ChromaFlair 190

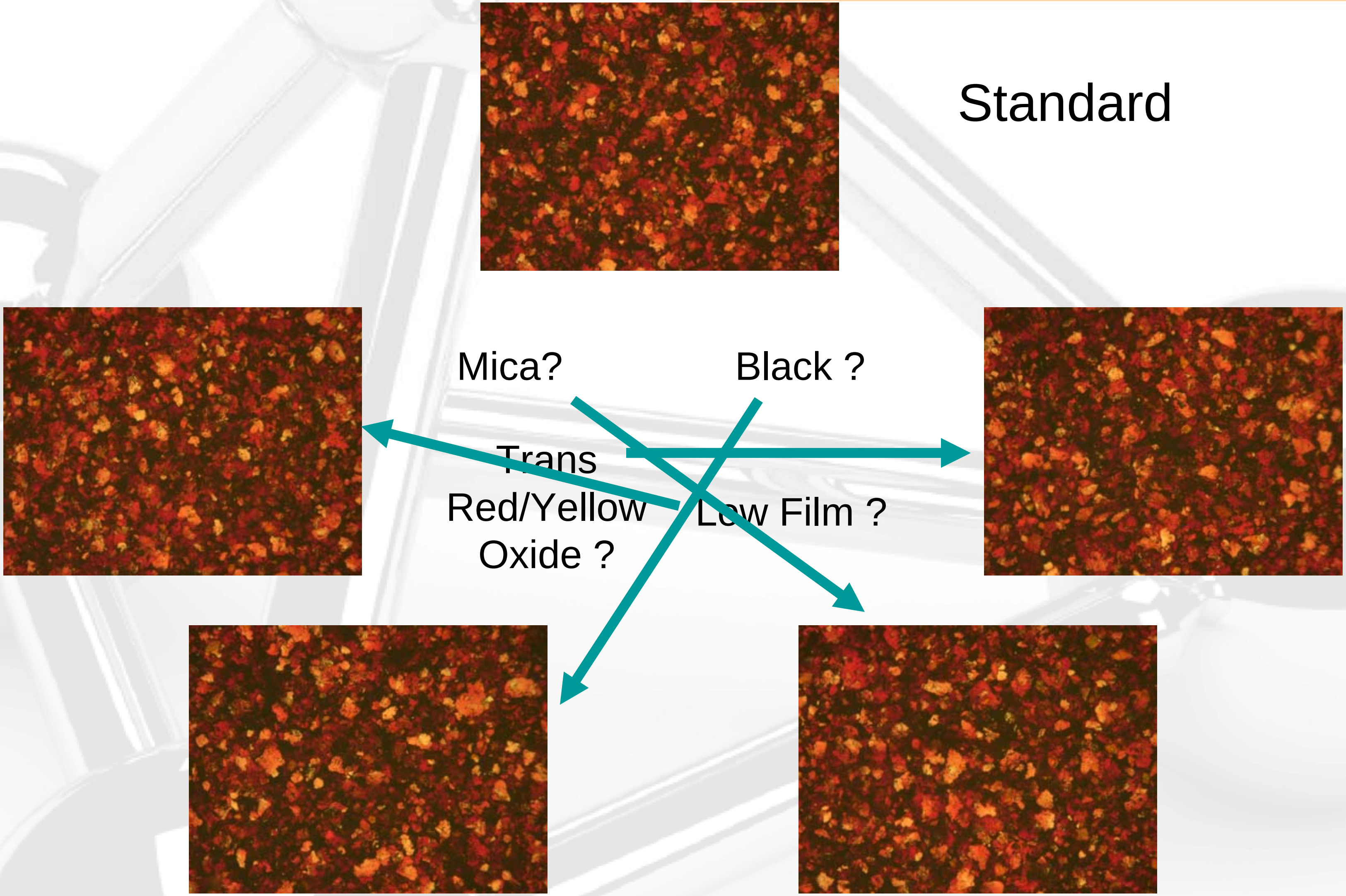
Limitations of a camera

- Sparkle and Coarseness are perceptual
- Flake contribution is goniometric
- Sparkle and Coarseness are goniometric



Which one is Xirallic?
Mica?

High Resolution Image Comparisons



The Coating DNA Concept:

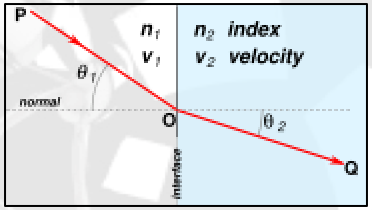
- Existing methodologies consisting of perceptual metrics such as L*a*b* do not provide information needed to drive root cause error detection of formulation and process changes.
- More direct material characterization methods do not provide perceptual based tolerances
- Spectroscopic measurements performed from different observation angles for a given illumination condition will characterize the scatter
  - Called the Bidirectional Reflectance Distribution Function
  - Energy must be conserved
    - Illuminating Light == Light absorbed + scattered + reflected

The Coating DNA Concept:

- All materials have a dielectric constant
  - The dielectric constants is dispersive (change with wavelength)
  - The optical refractive index is proportional to the square root of the dielectric constant
  - All materials can be described and determined through their optical response
- All materials will scatter light
  - Due to physical and molecular make up.
  - Scatter is wavelength dependent
    - Independent of color. Which is, remember, perceptual
  - How the light is scattered can be directly related to the type and make up of the material
- Effective Medium Theory
  - Multi ingredient models as "single material"

$$\varepsilon_r = \frac{C_x}{C_0}$$

$$n = \frac{c}{v}$$

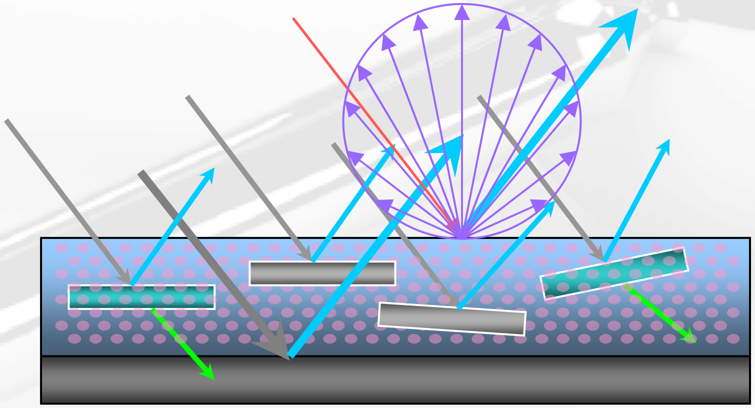


The Coating DNA Concept:

- Light does not reflect right at the surface
- Most materials are not opaque
- Sub surface scatter creates a unique signature for every coating / material
  - Each recipe has a unique signature
  - Each process transforms unique signature
  - Variation and distribution (formulation) modifies unique signature
- Application of constraints directs:
  - How to process data
  - Which model to apply.

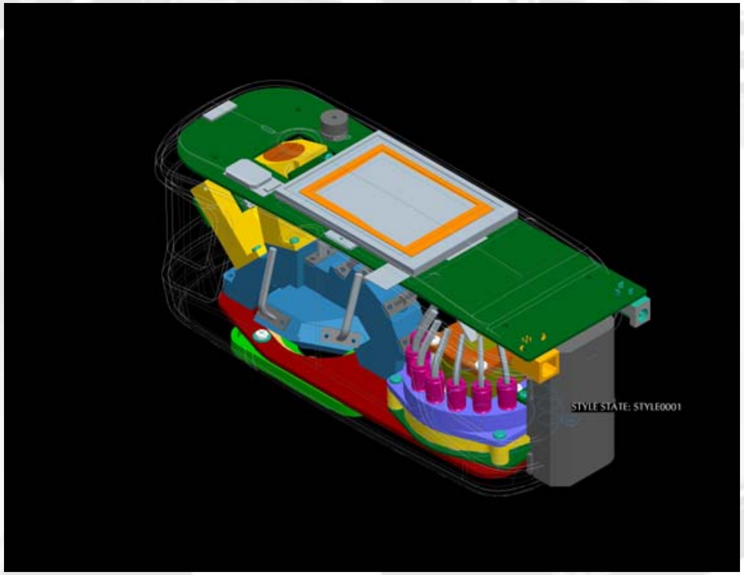
The Hardware Challenge

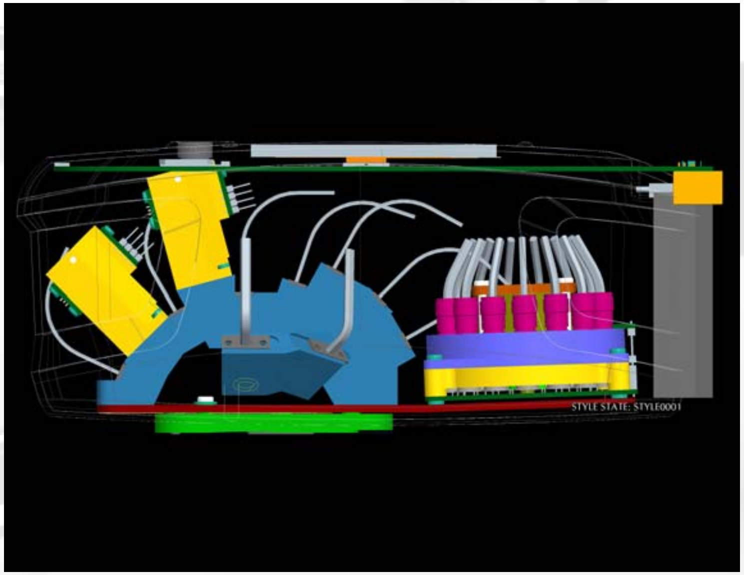
- How to measure a BRDF/BSSRDF in 1 second?
  – Market need to correlate to existing MA68 databases
- How many look angles?
  – Minimally must also include original MA68 angles
- How many illumination angles?
- Marketing requirements for backwards compatibility



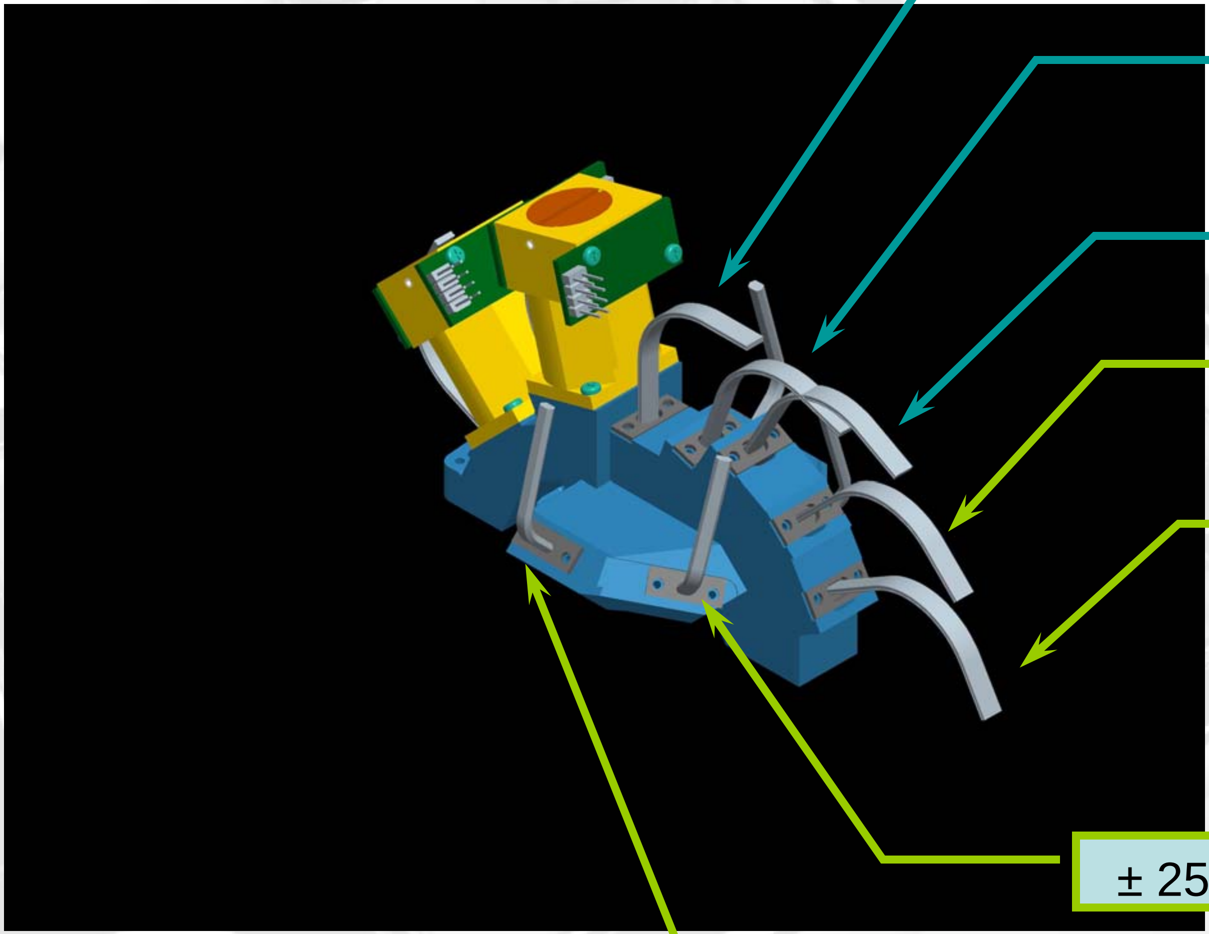
Hardware

- The MA98
  - A Industrial Grade multichannel spectrometer for BSSDF
    - 11 measurement angles
    - 2 illumination angles
  - Provides industry migration from existing MA68 standards to BRDF/BSSRDF based

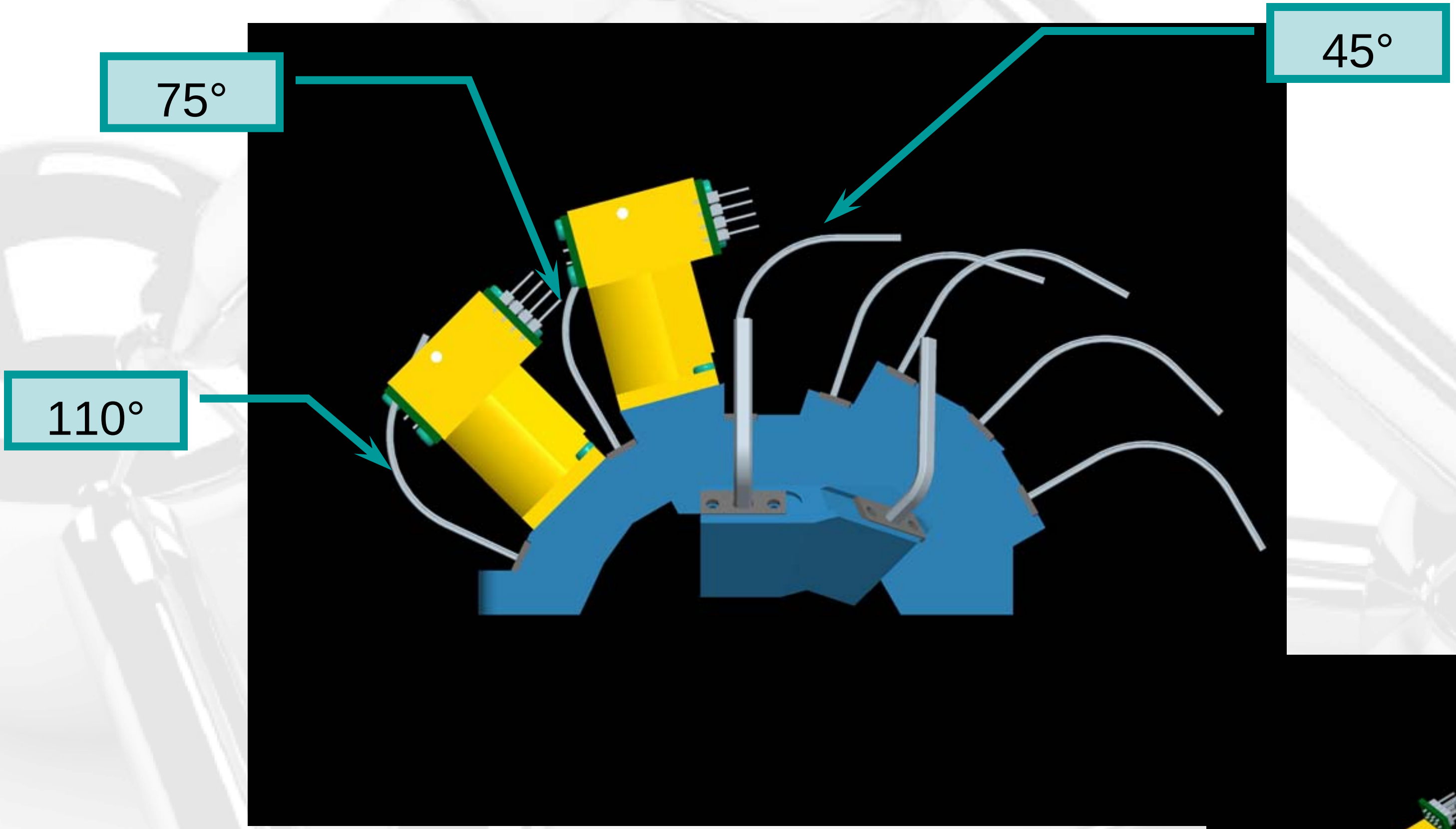


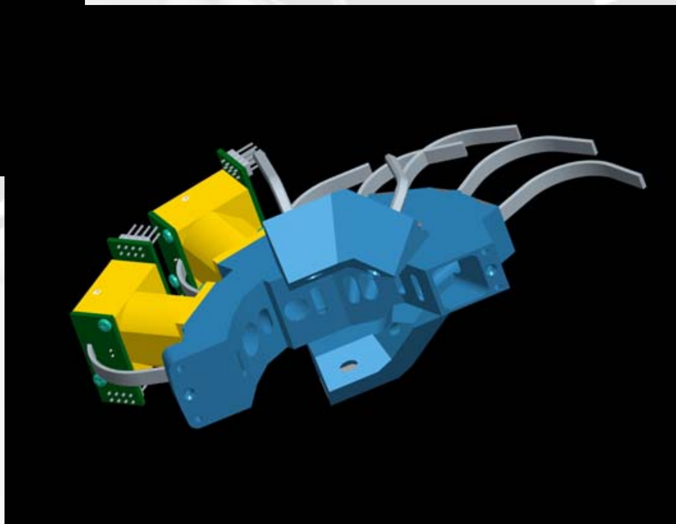


Geometry



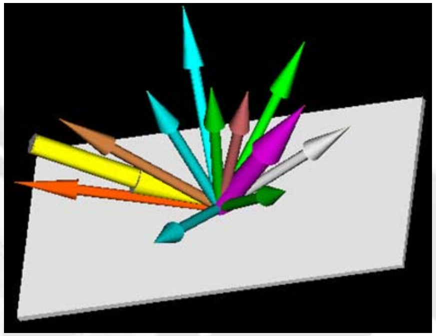
Geometry





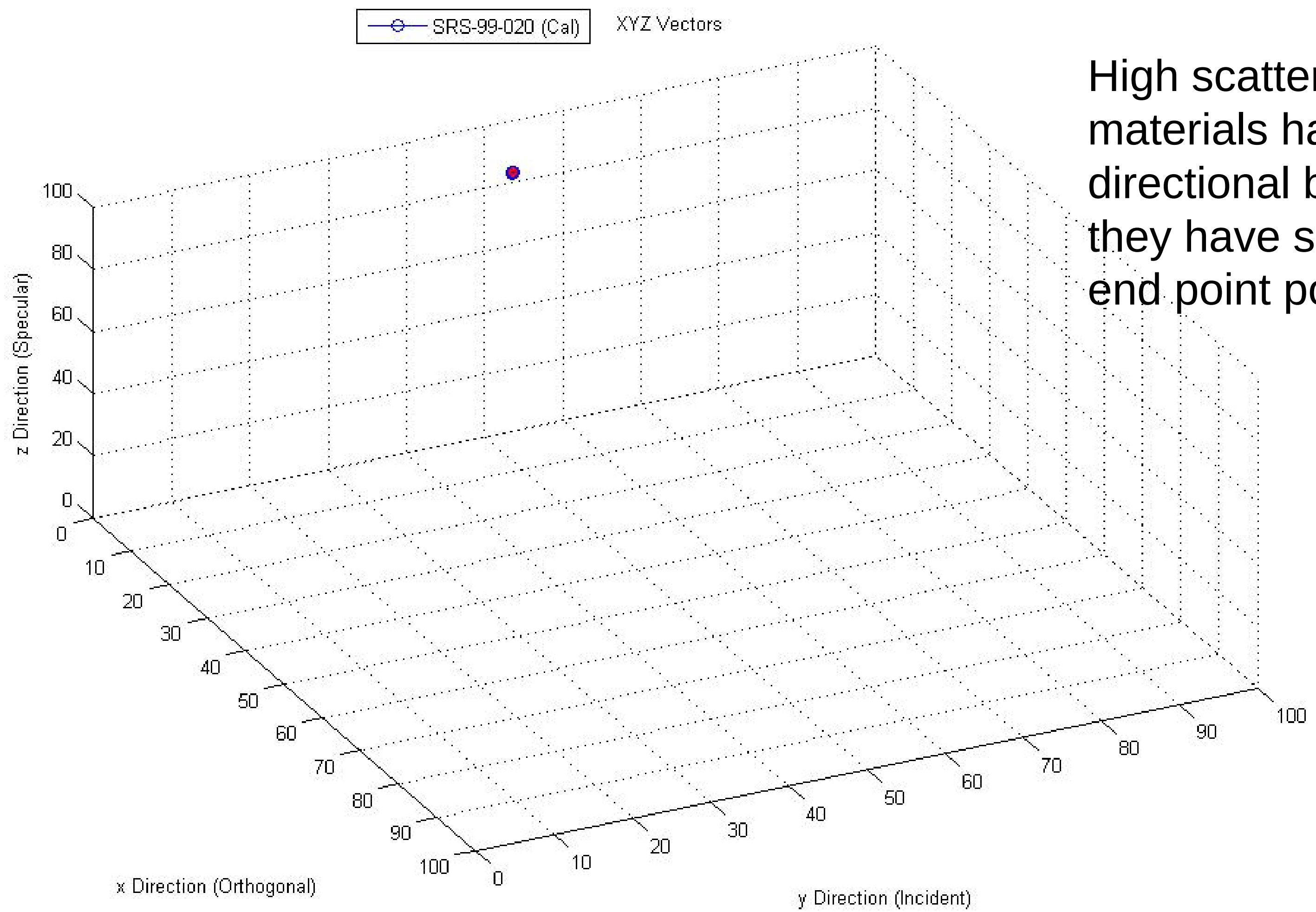
Computational Statistics:
X-Rite Color DNA®

- DNA is expressed through a statistic that represents a spatially weighted bias of the spectral BSSRDF measurement function
- Bias functions are represented in 3D space
  - Nominally in reference frame of instrument
    - Z is along specular axis
    - Y in along illumination axis
    - X is out the side of the instrument



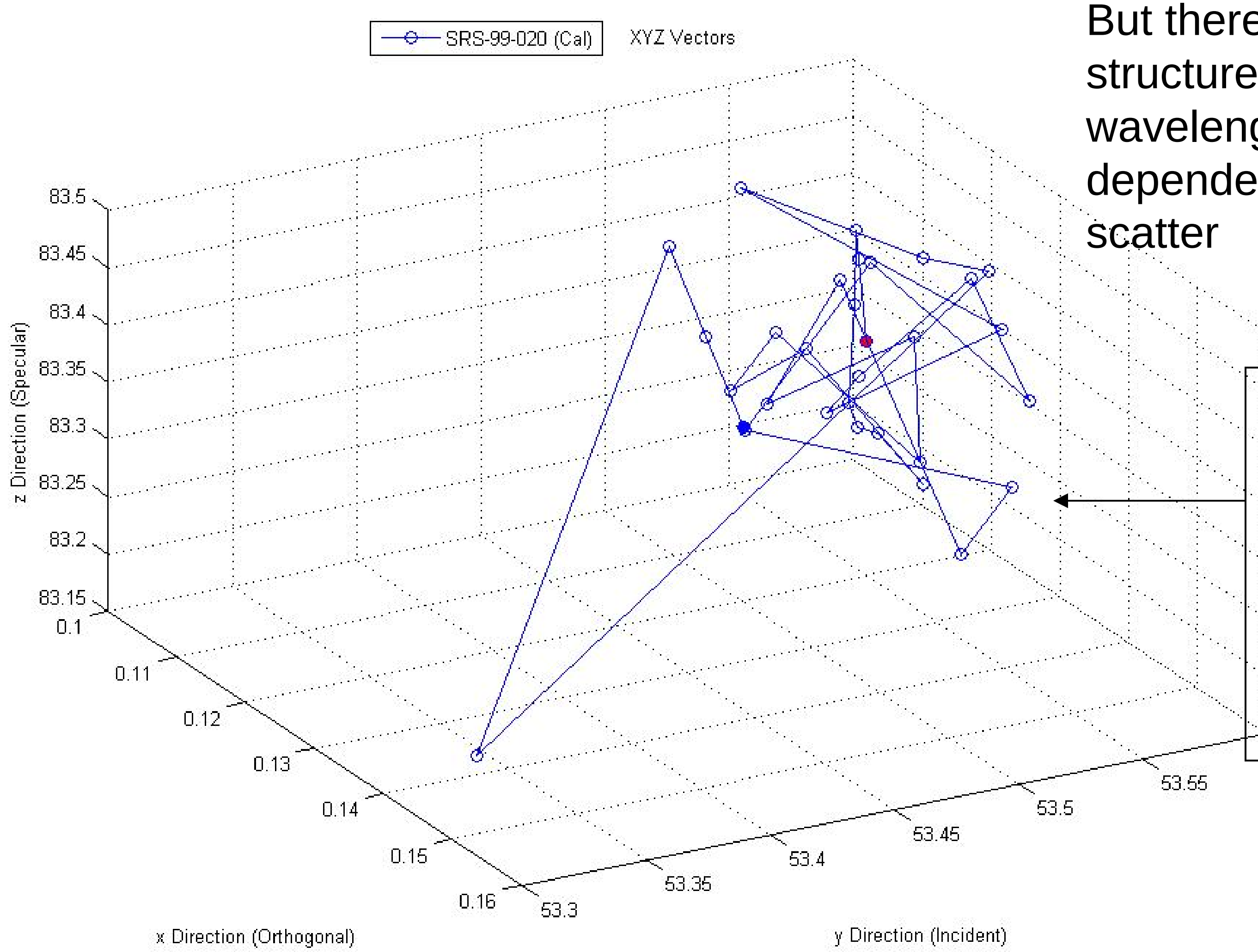
- Bias functions consist of 31 points representing the spectral bands
- Translation and rotation of DNA print represent process variation
- Shape change represents formulation change
- A small spatial distribution represents uniform scatter (no bias)
- Large spatial distribution represents presence of absorption and effect color travel

Spectralon example



High scattering materials have little directional bias so they have similar end point positions

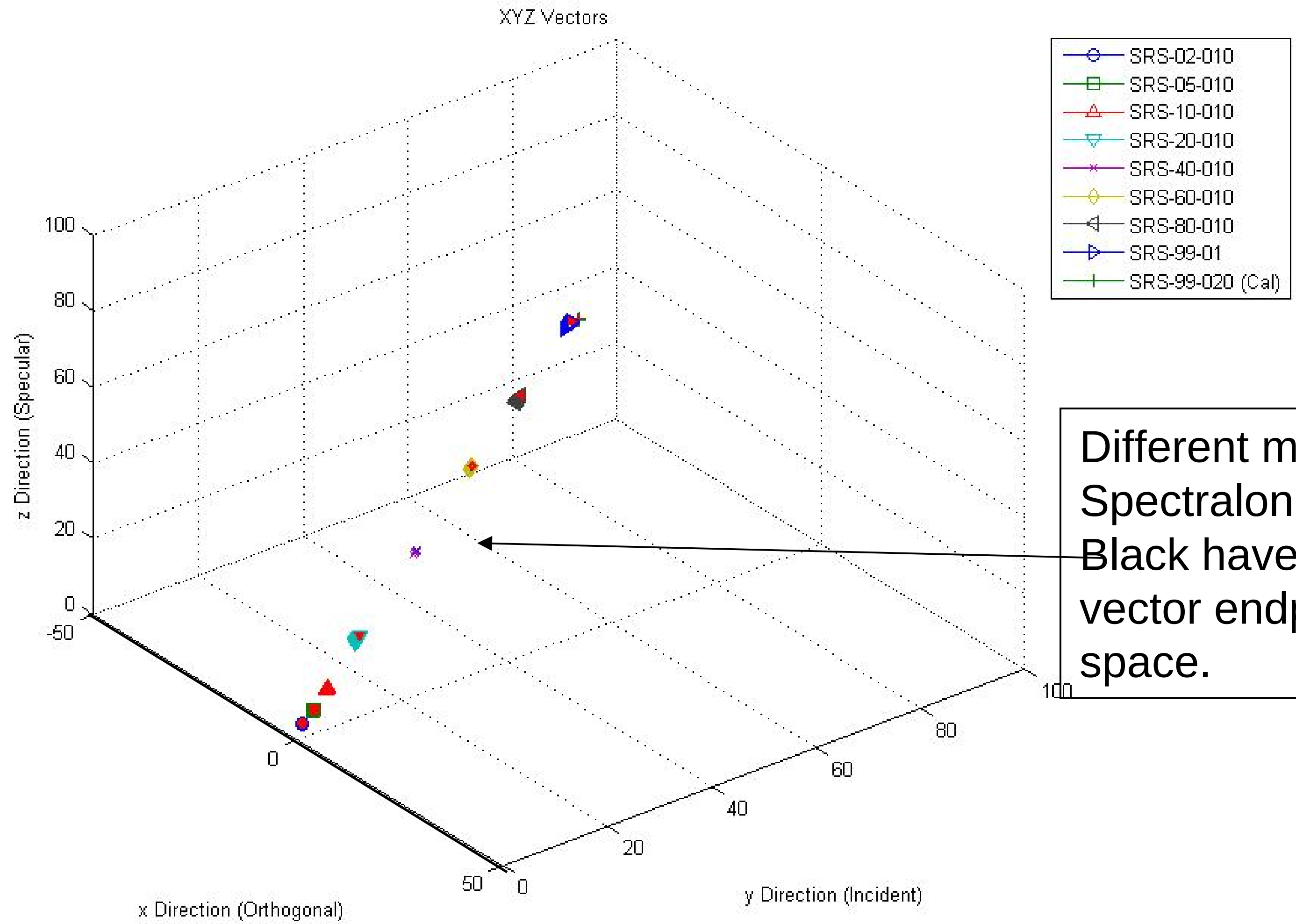
Spectralon example



But there is still structure due to wavelength dependent scatter

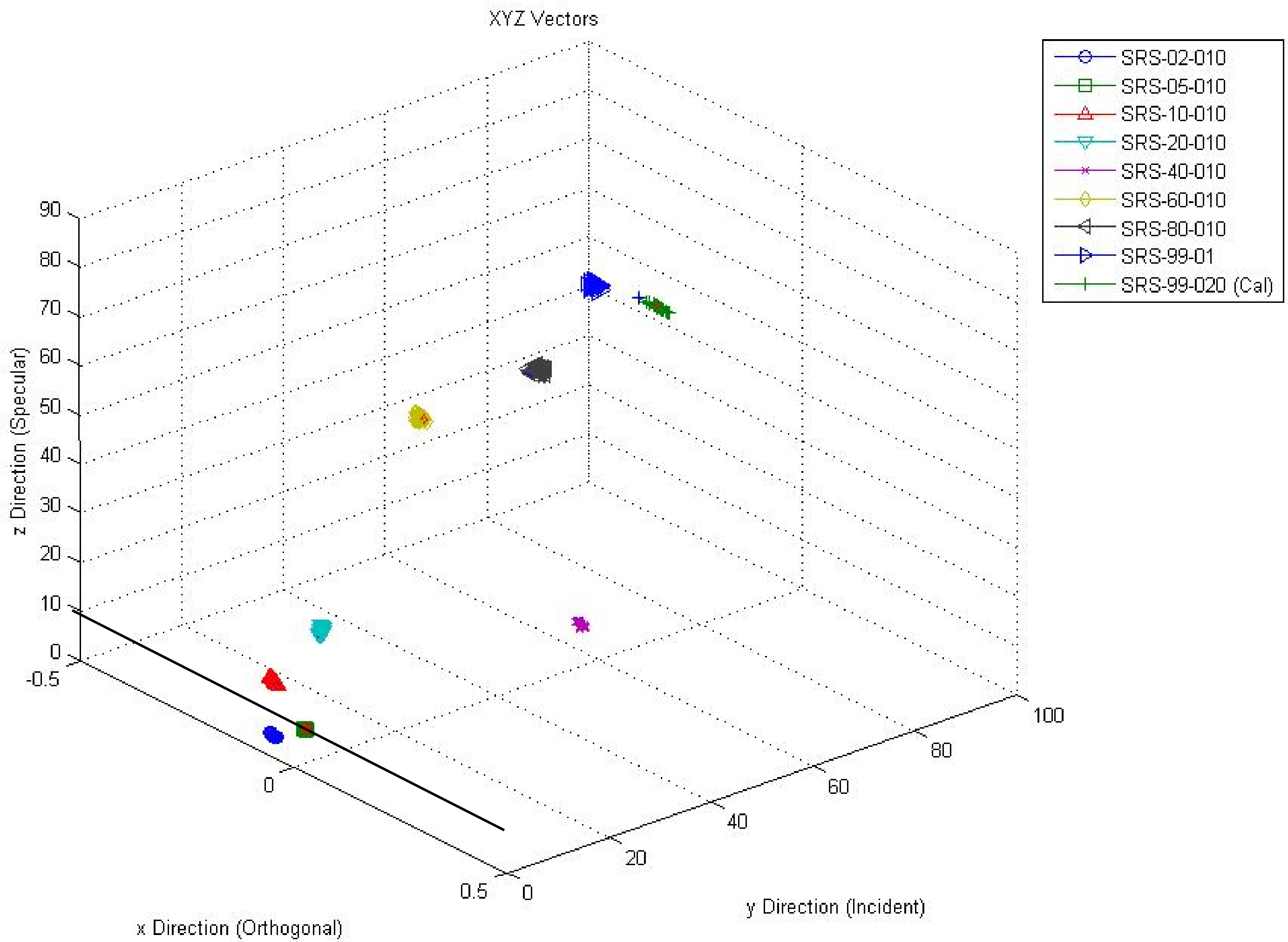
Each point corresponds to the sum of reflectances, for all angles, at a single wavelength.

Spectralon



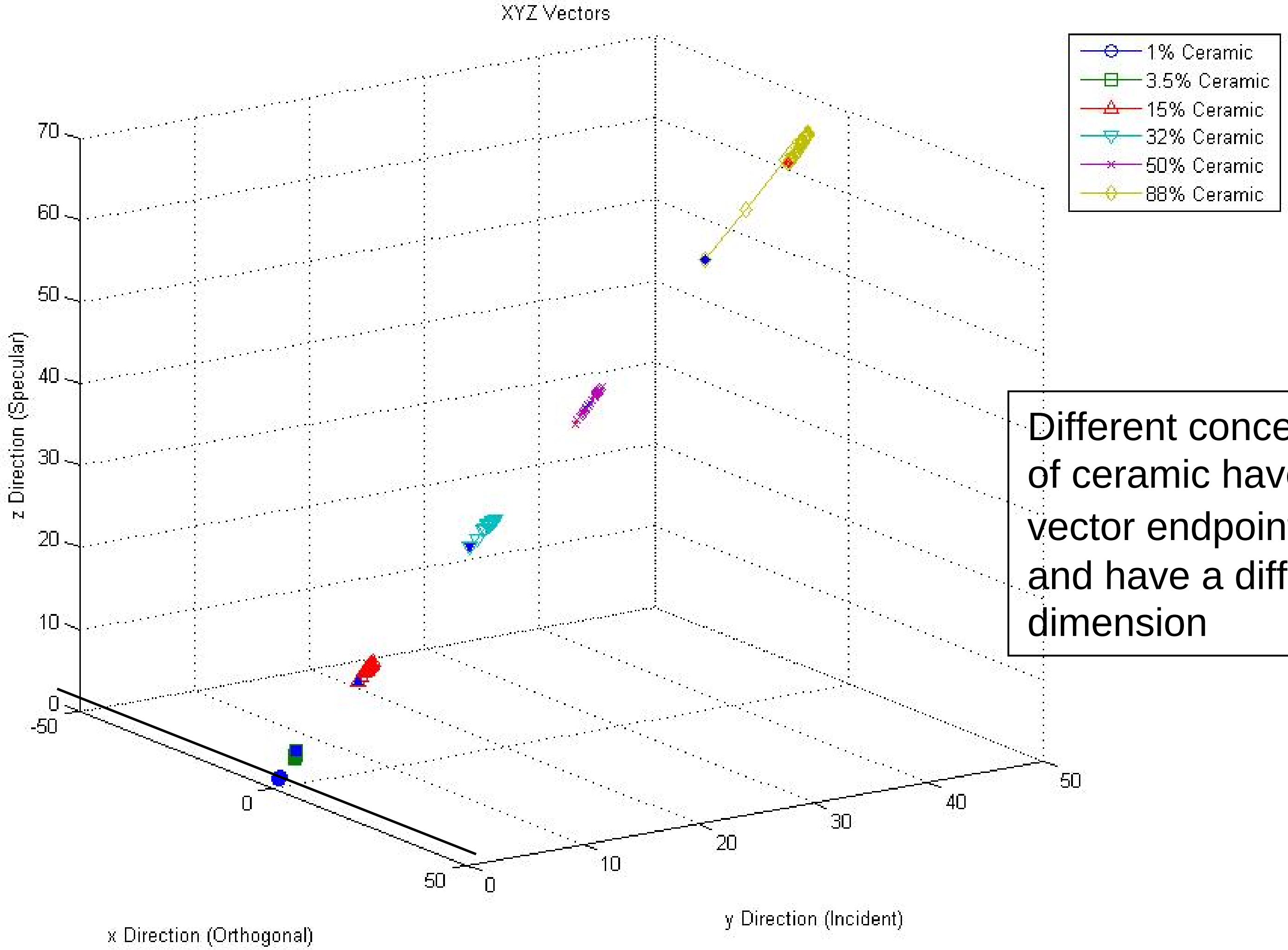
Different mixtures of Spectralon with Black have different vector endpoints in space.

Spectralon



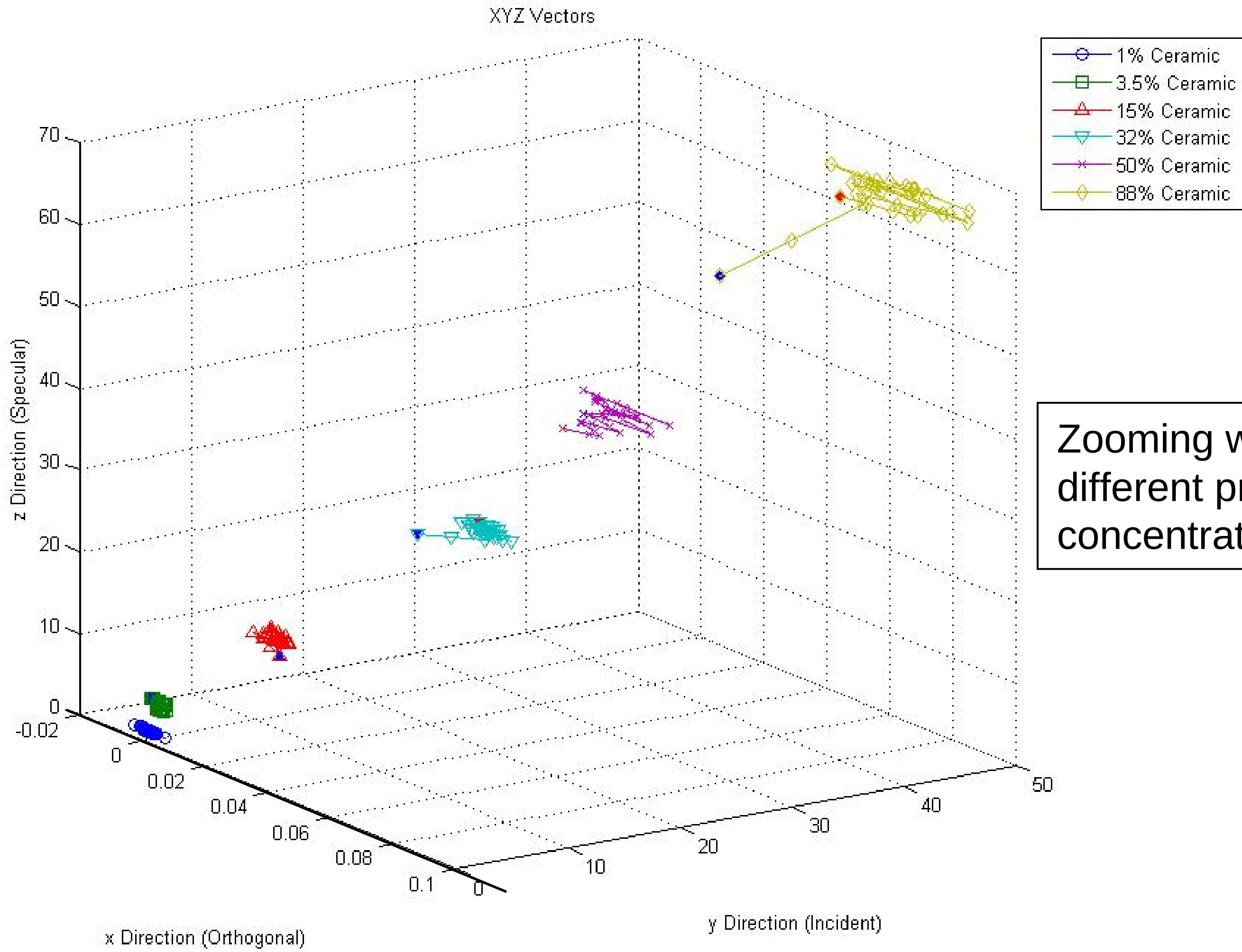
XYZ Vectors
SRS-02-010
SRS-05-010
SRS-10-010
SRS-20-010
SRS-40-010
SRS-60-010
SRS-80-010
SRS-99-01
SRS-99-020 (Cal)
z Direction (Specular)
90
80
70
60
50
40
30
20
10
0
-0.5
0
0.5
x Direction (Orthogonal)
0
20
40
60
80
100
y Direction (Incident)

White Ceramic Tile Examples



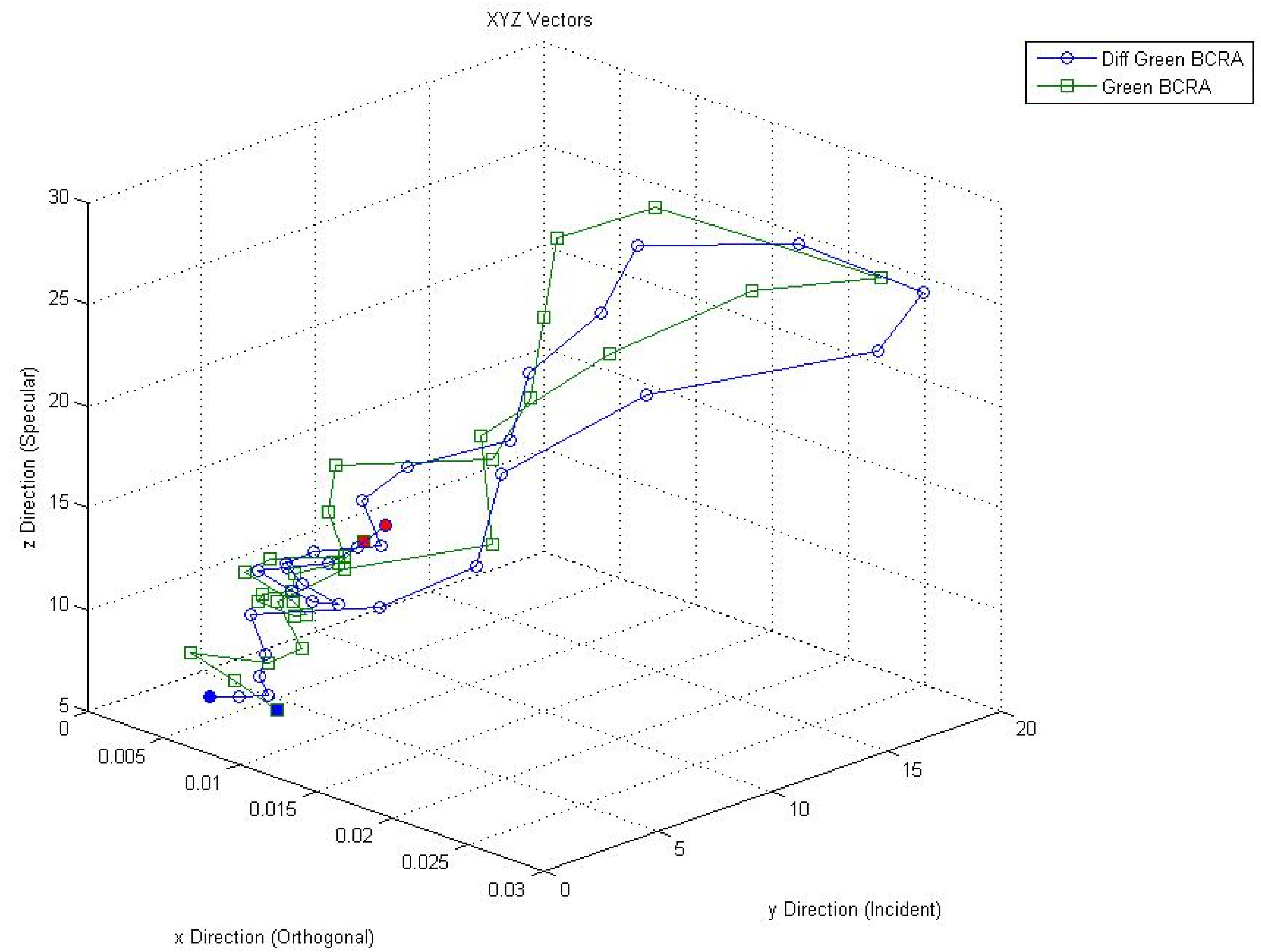
Different concentrations of ceramic have different vector endpoints in space and have a different dimension

White Ceramic Tile Example

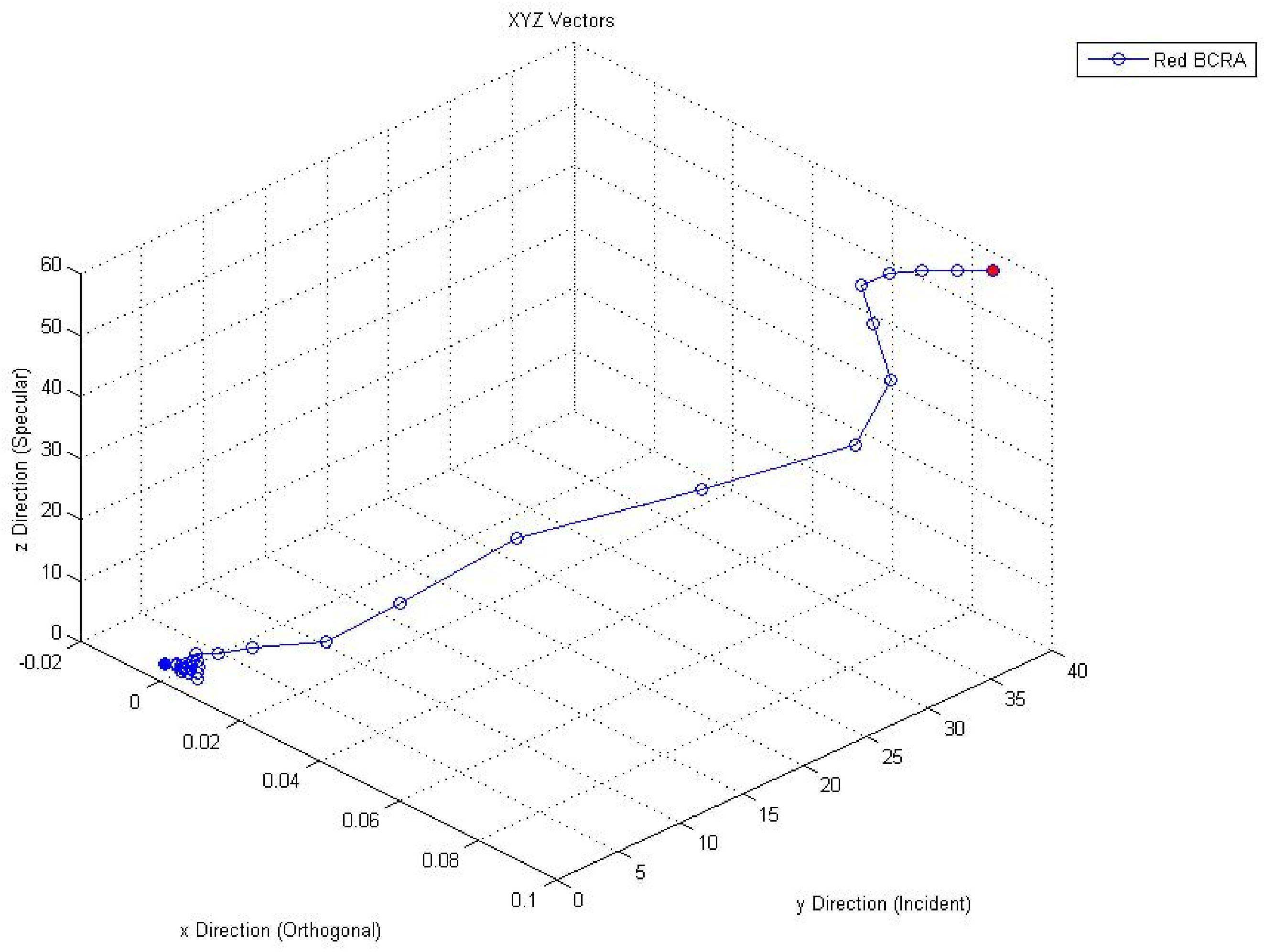


Zooming will show a different profile for each concentration

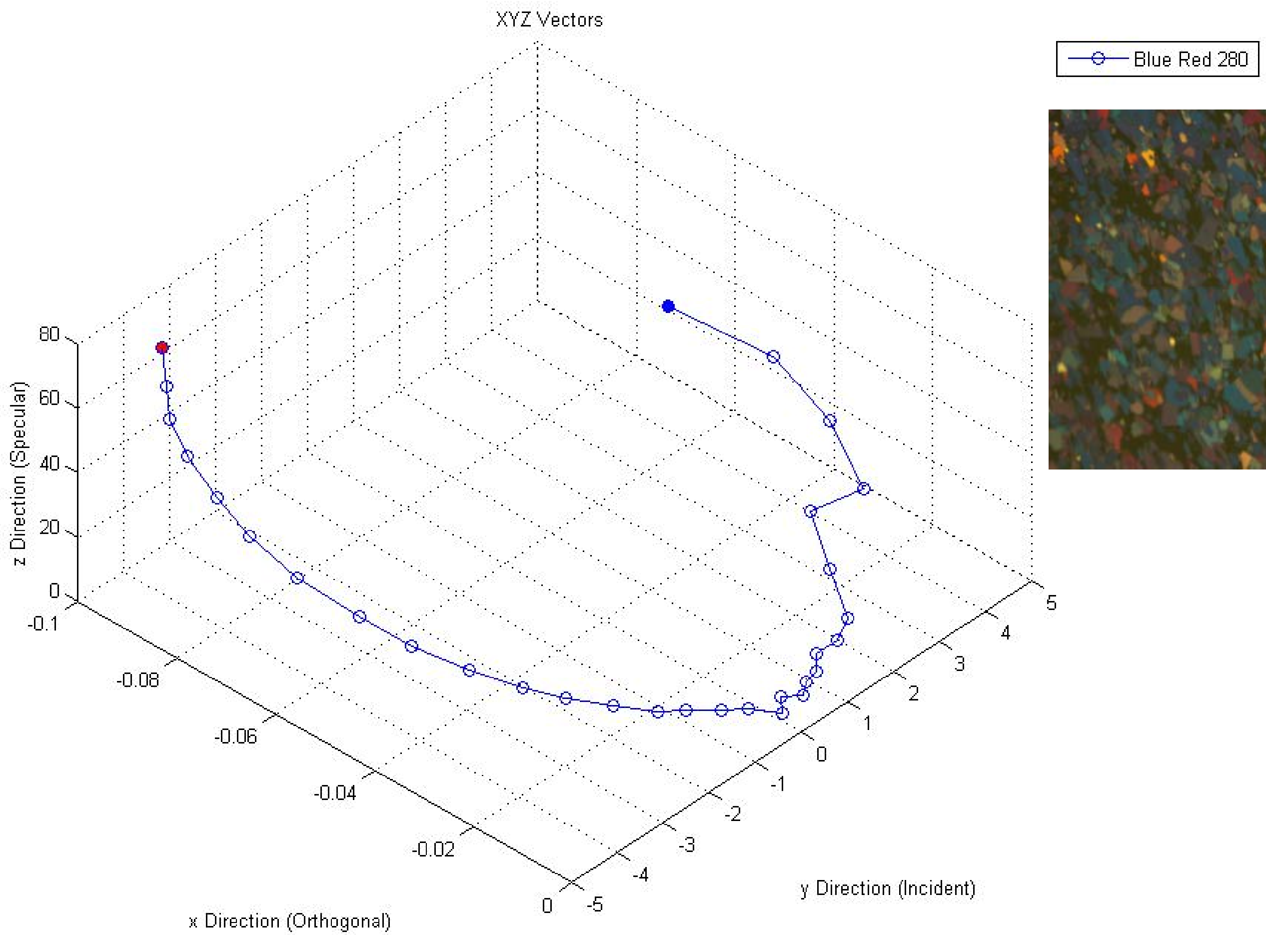
Green Ceramic Tile Examples

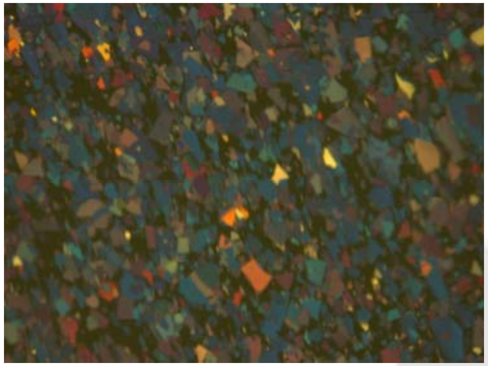


Pure Absorptive Pigment Examples

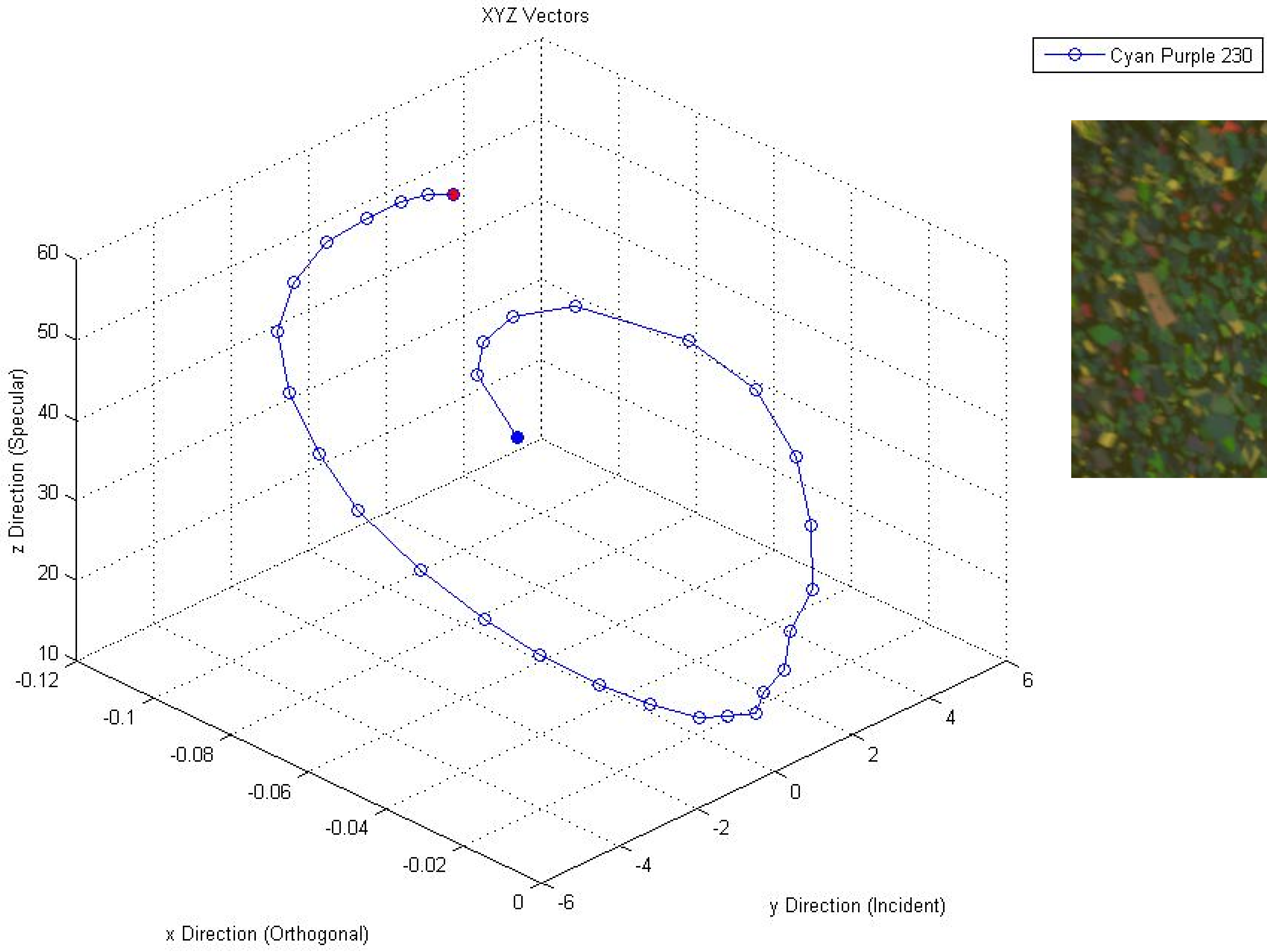


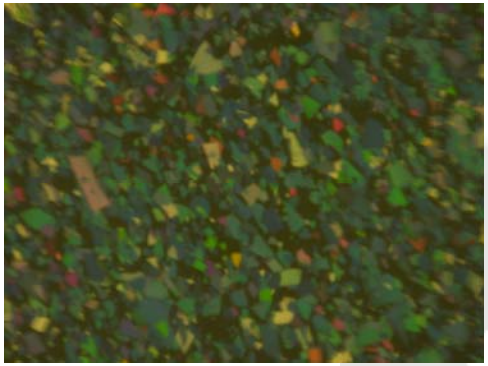
Chroma Flair Examples



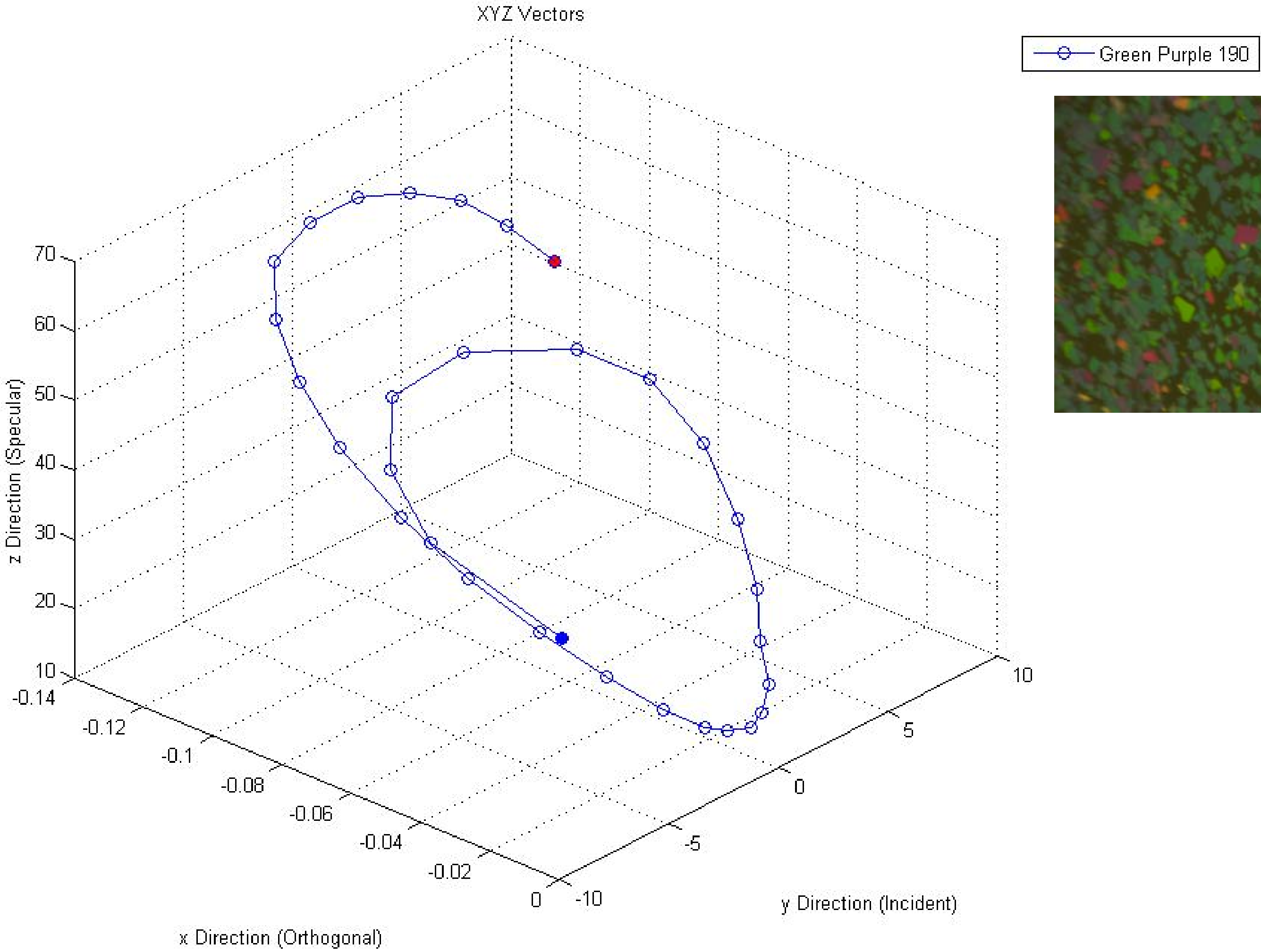


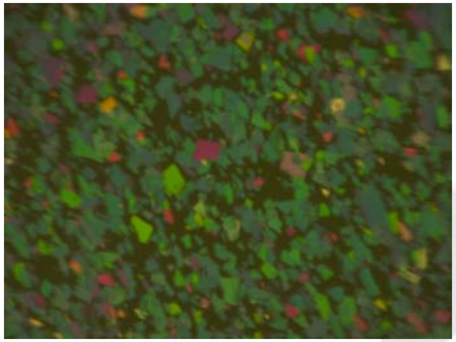
Chroma Flair Examples



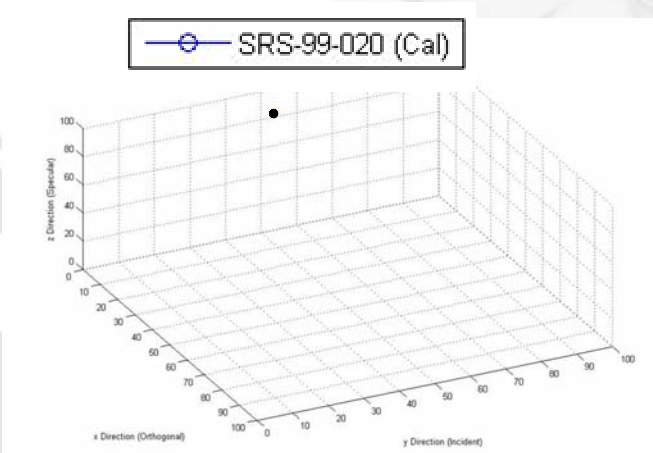


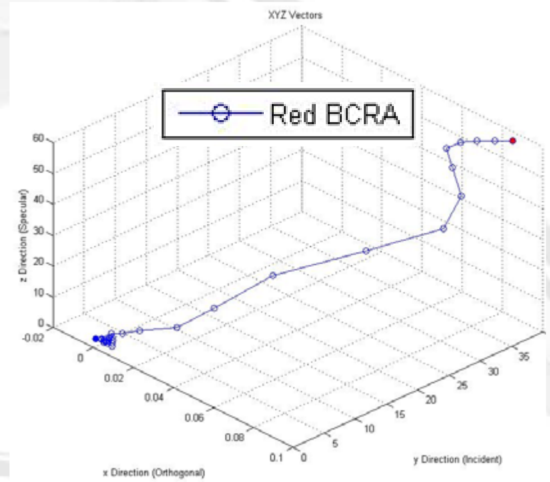
Chroma Flair Examples

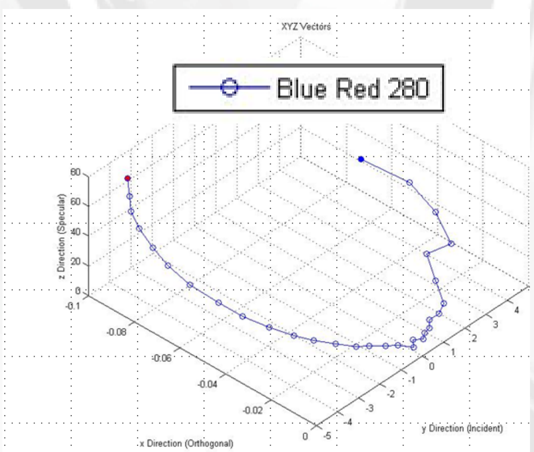


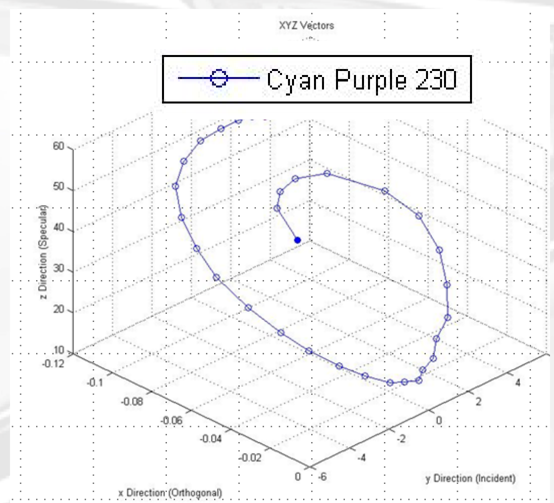


Material Profiles









Each material has it's specific vector endpoint profile.

High scattering materials have little directional bias so they have similar end point positions

Absorptive pigments show line structures due to specific wavelength absorptions

Effect materials show a loop profiles due to wavelength dependent directional bias

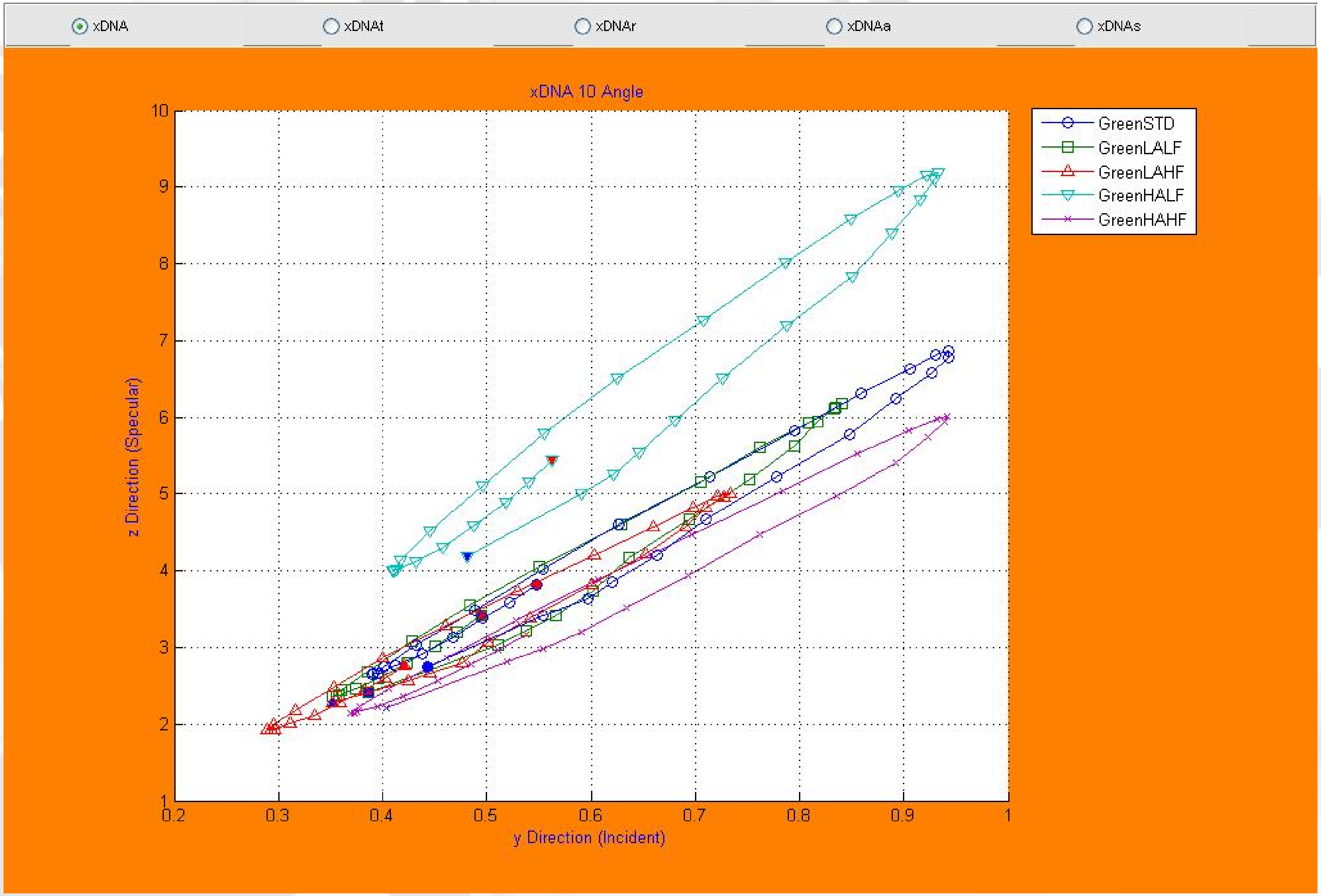
- Process Variables
  - Flow and Atomization

Low Flow & High Atomization

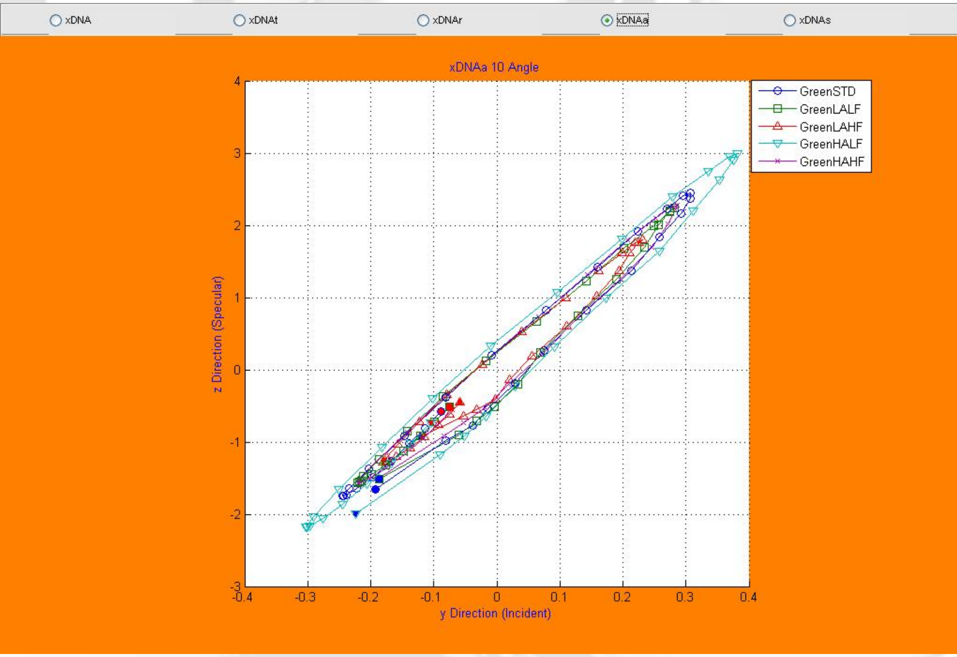
High Flow & Low Atomization

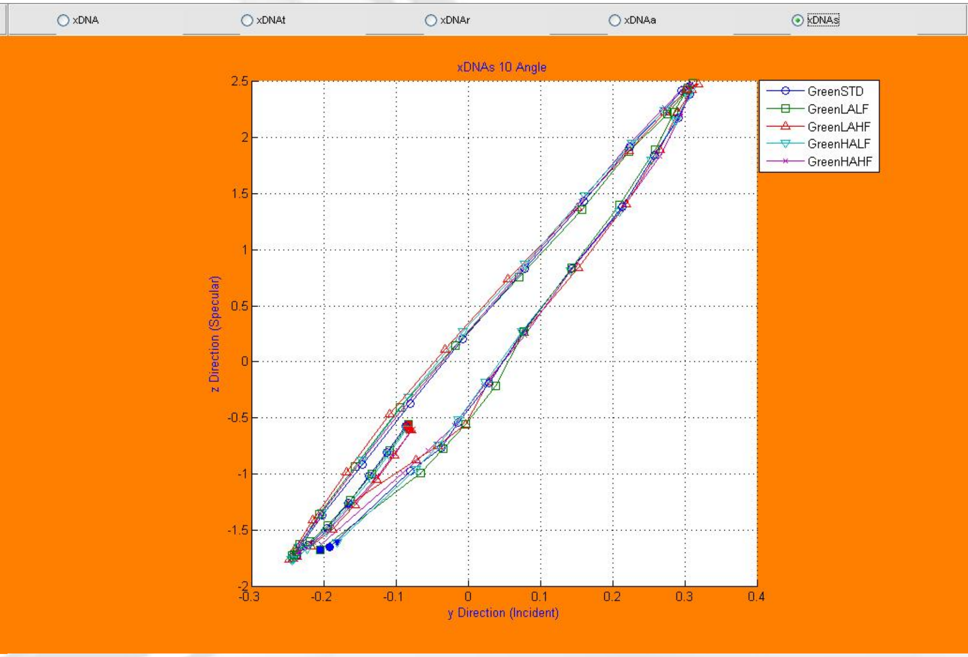
Process Variation

- Pattern Offset Indicates Visual Differences



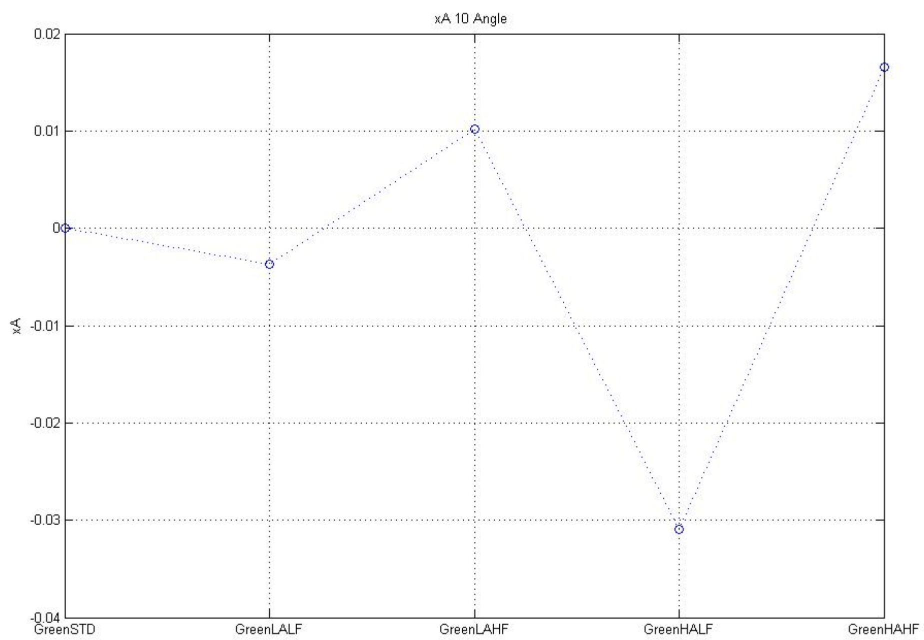
- Pattern match after translation, rotation and scaling indicates identical formula

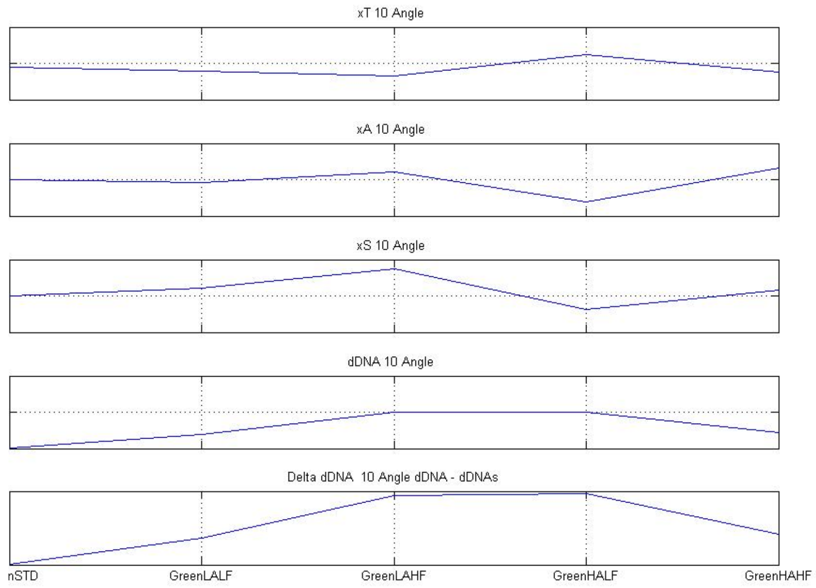




Process Variation

- Analysis of data variations correlate to process variations



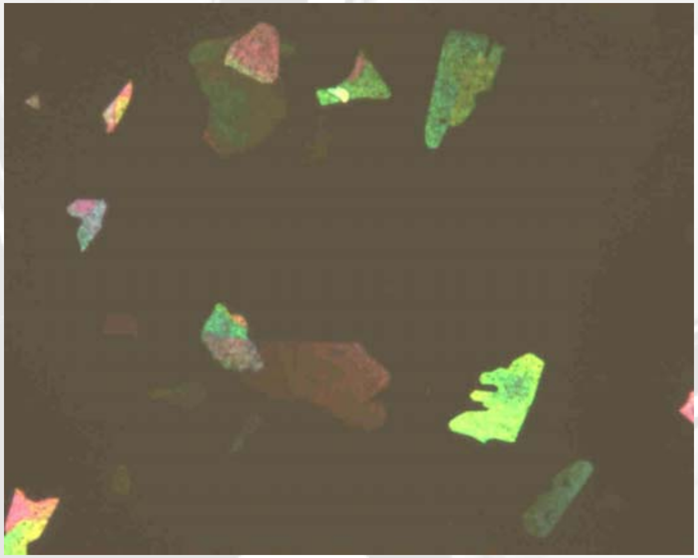


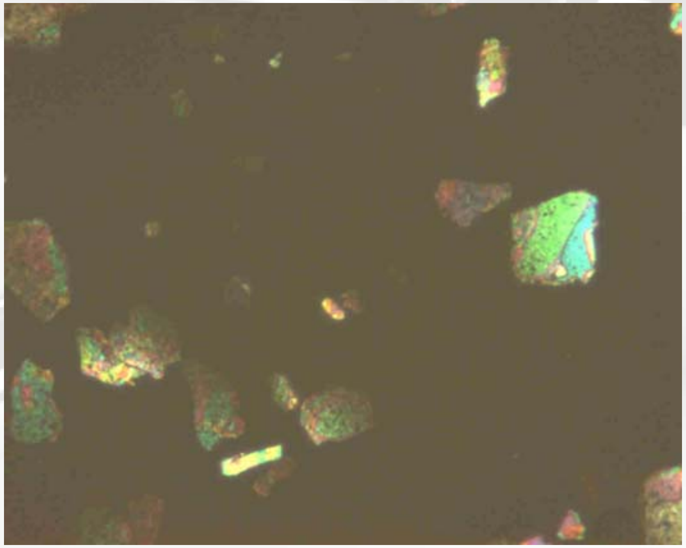
Formula Differences

- 2 samples – visually different but MA68II couldn‘t measure any difference

MA939.35	SOLVENT BALANCE	18.85
MA939.35	PHTHALO BLUE	5.36
MA939.35	JET BLACK	43.84
MA939.35	LAMP BLACK	19.70
MA939.35	PITCH CONTROLLER	5.96
MA939.35	XIRALLIC CRYSTAL SILVER	6.29

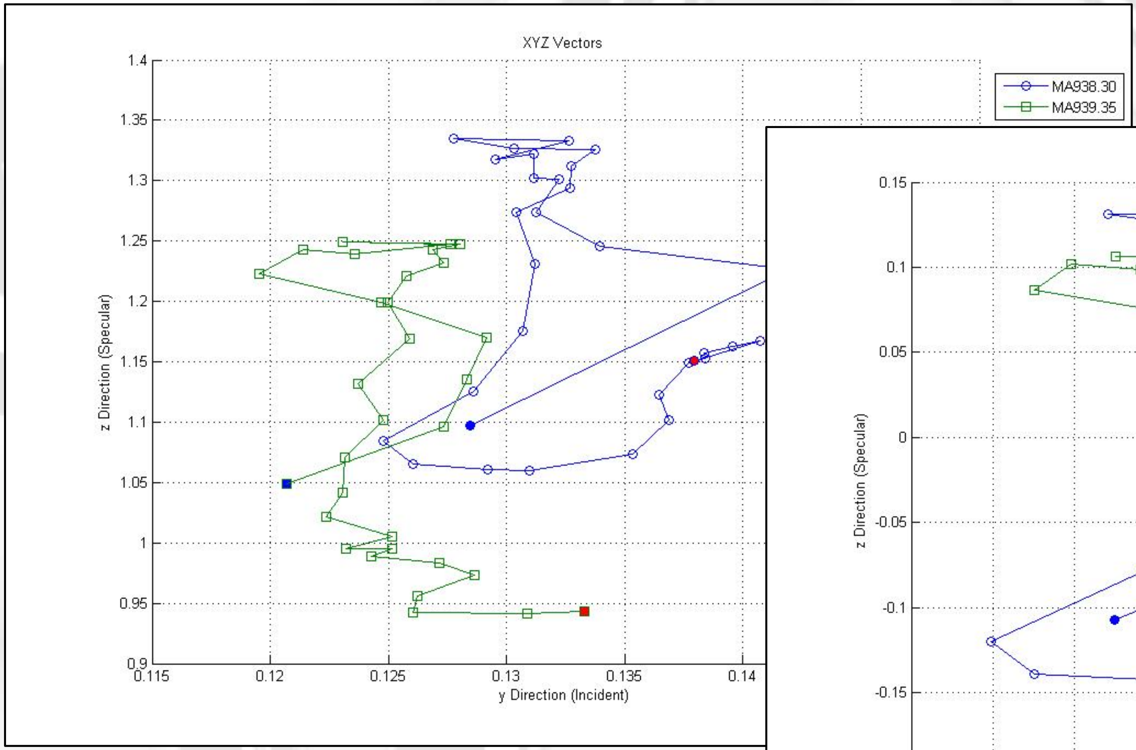
MA938.30	SOLVENT BALANCE	19.14
MA938.30	LS WHITE	1.74
MA938.30	PHTHALO BLUE	5.86
MA938.30	BLACK	68.60
MA938.30	MED WHITE MICA	4.66

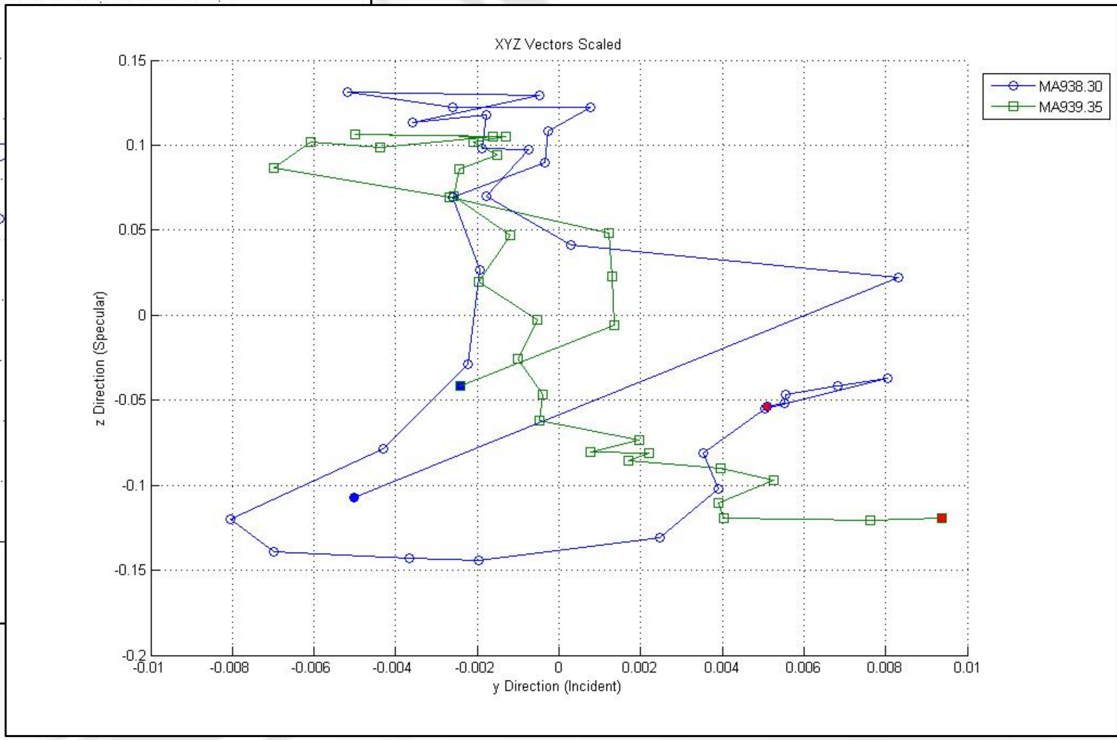




Formula Differences

- Pattern Offset Indicates Visual Differences

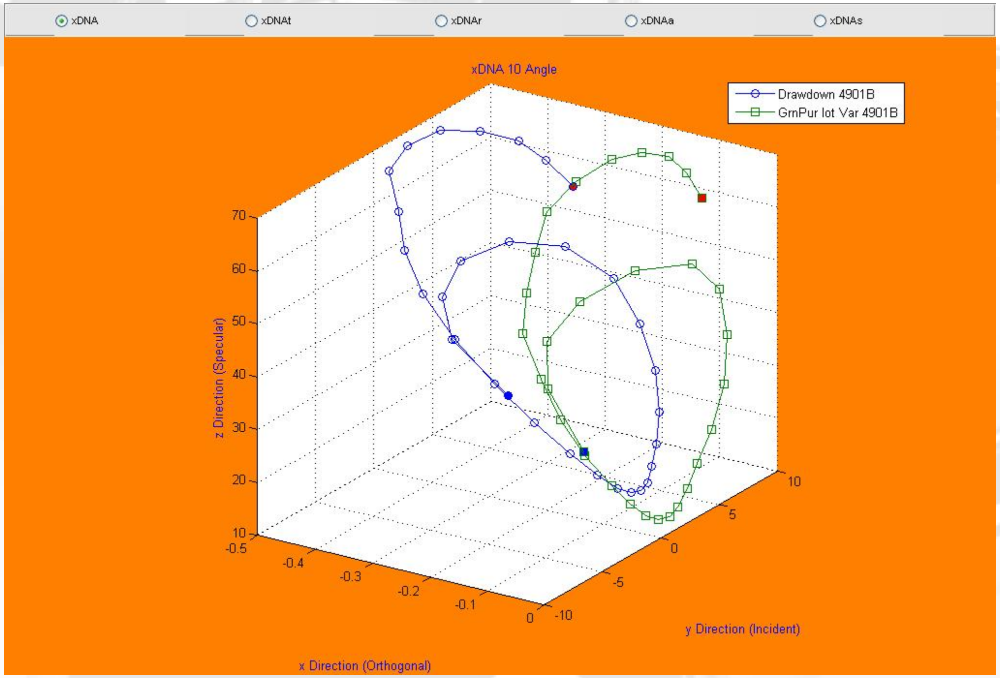


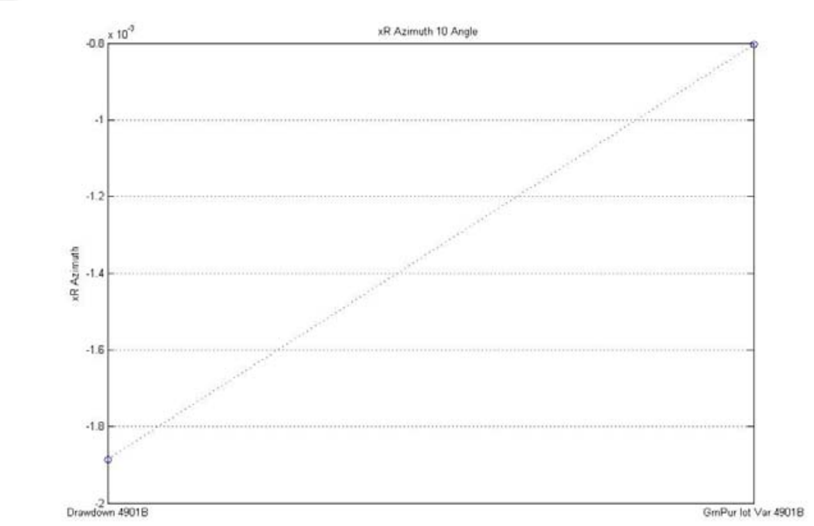


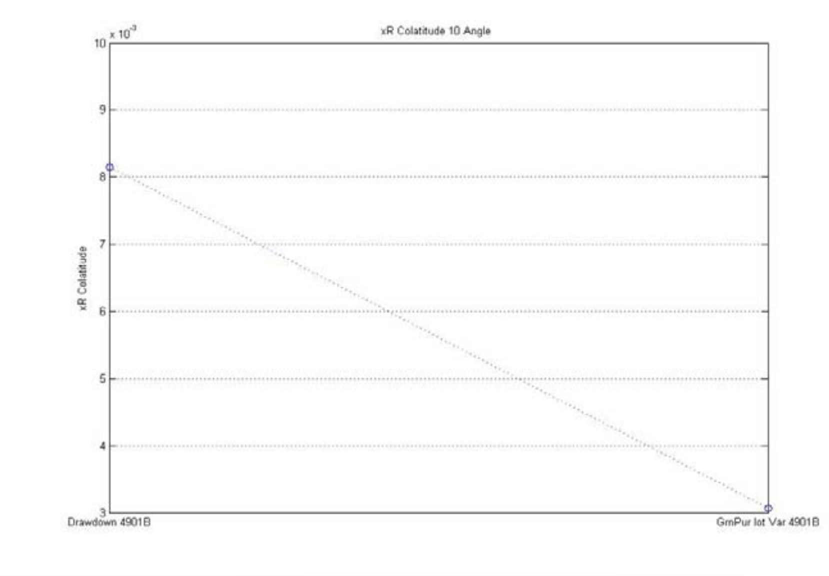
- Pattern Mis-Match after Translation,
  Rotation and scaling indicates Formula Differences

Flake Angle

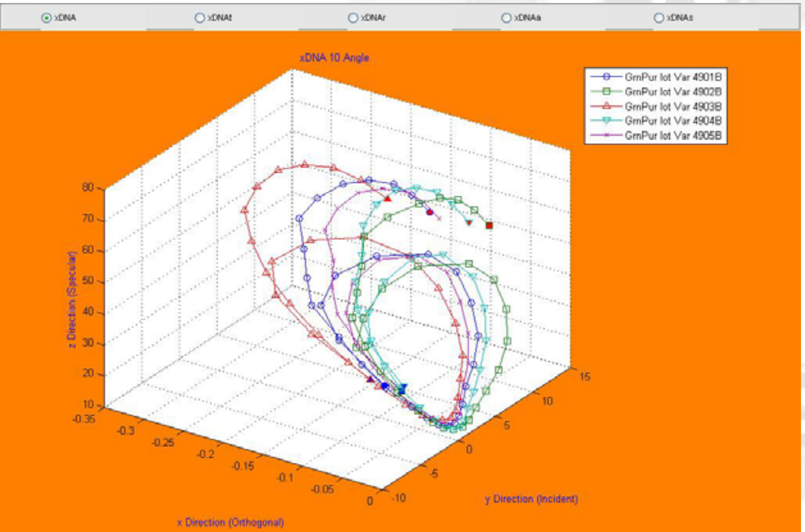
- Fit plane to pattern ↔ Compute angles relative to instrument ↔ transfer into coordinate system of sample measurement plane

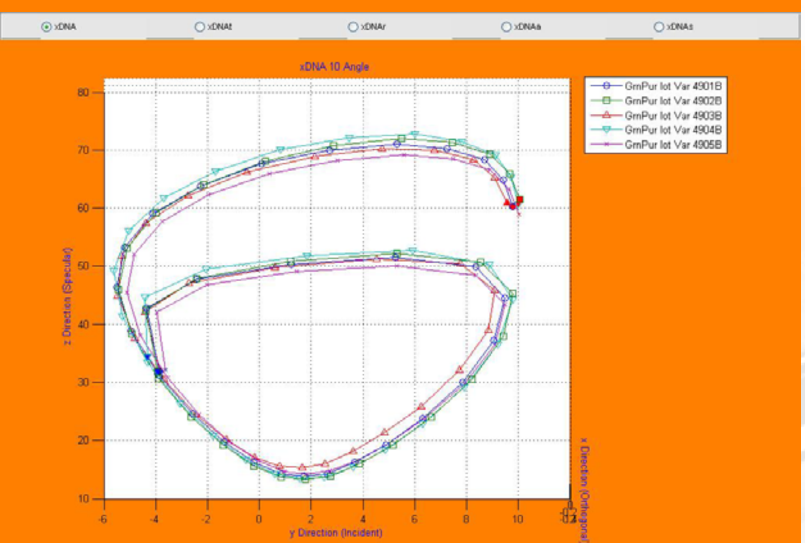




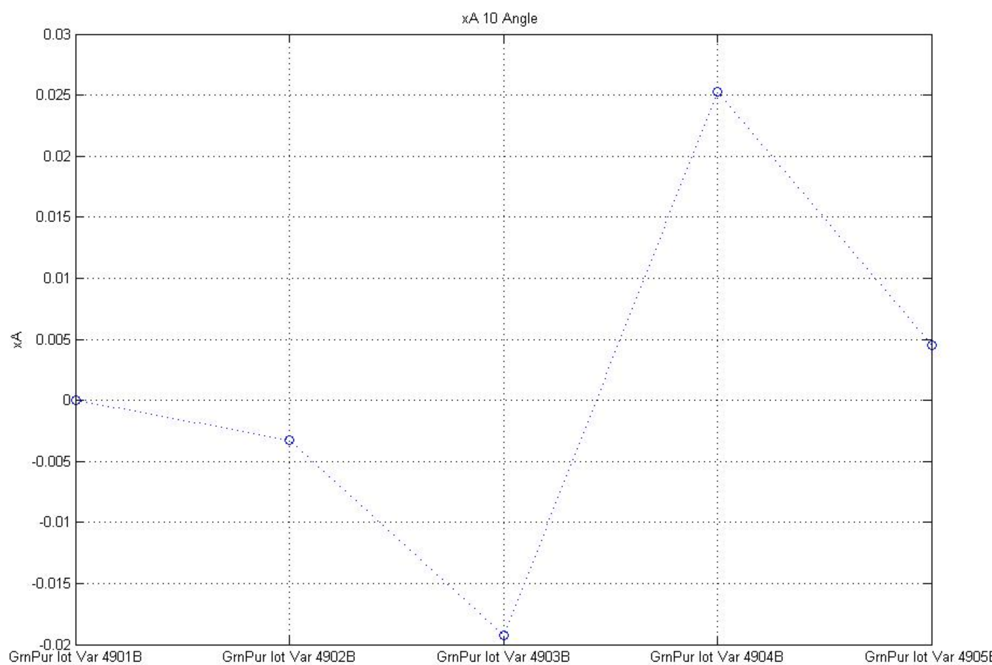


- Multiple lots with variance between lots

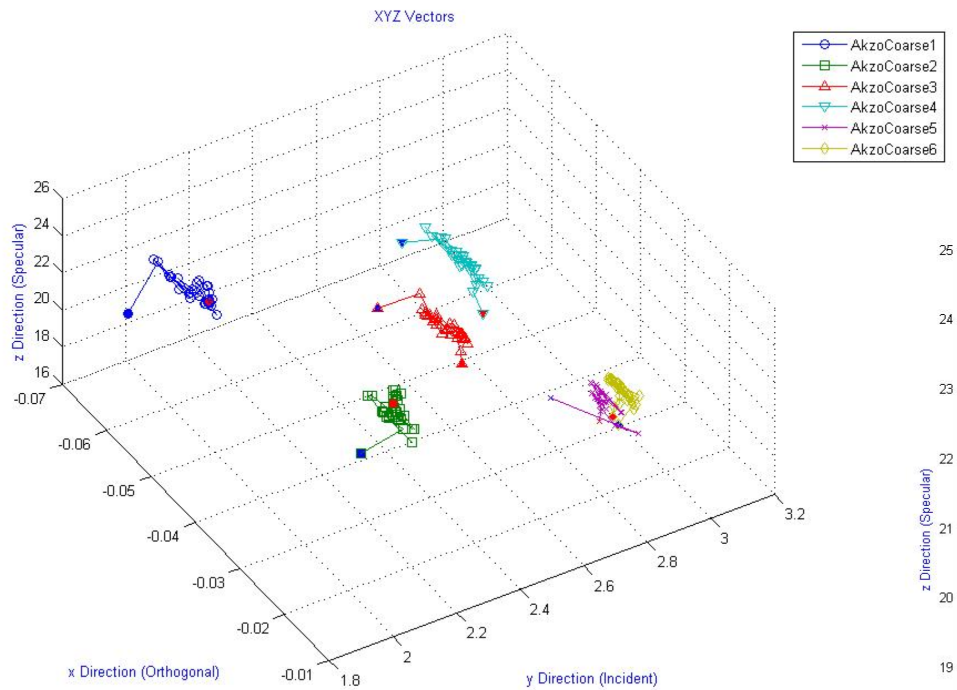


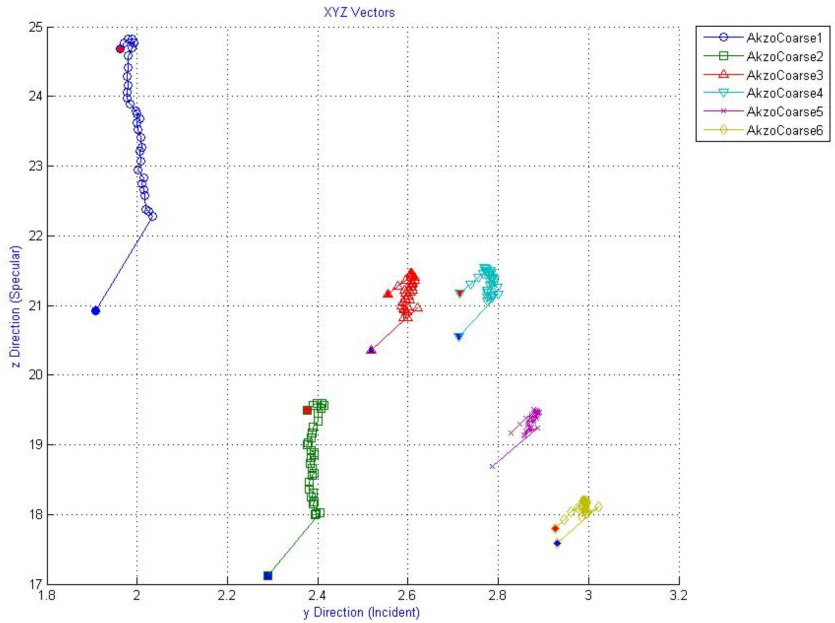


More diffuse ↔ End points closer together ↔ Smaller Particles ↔ Increased fines or smaller mean flake size

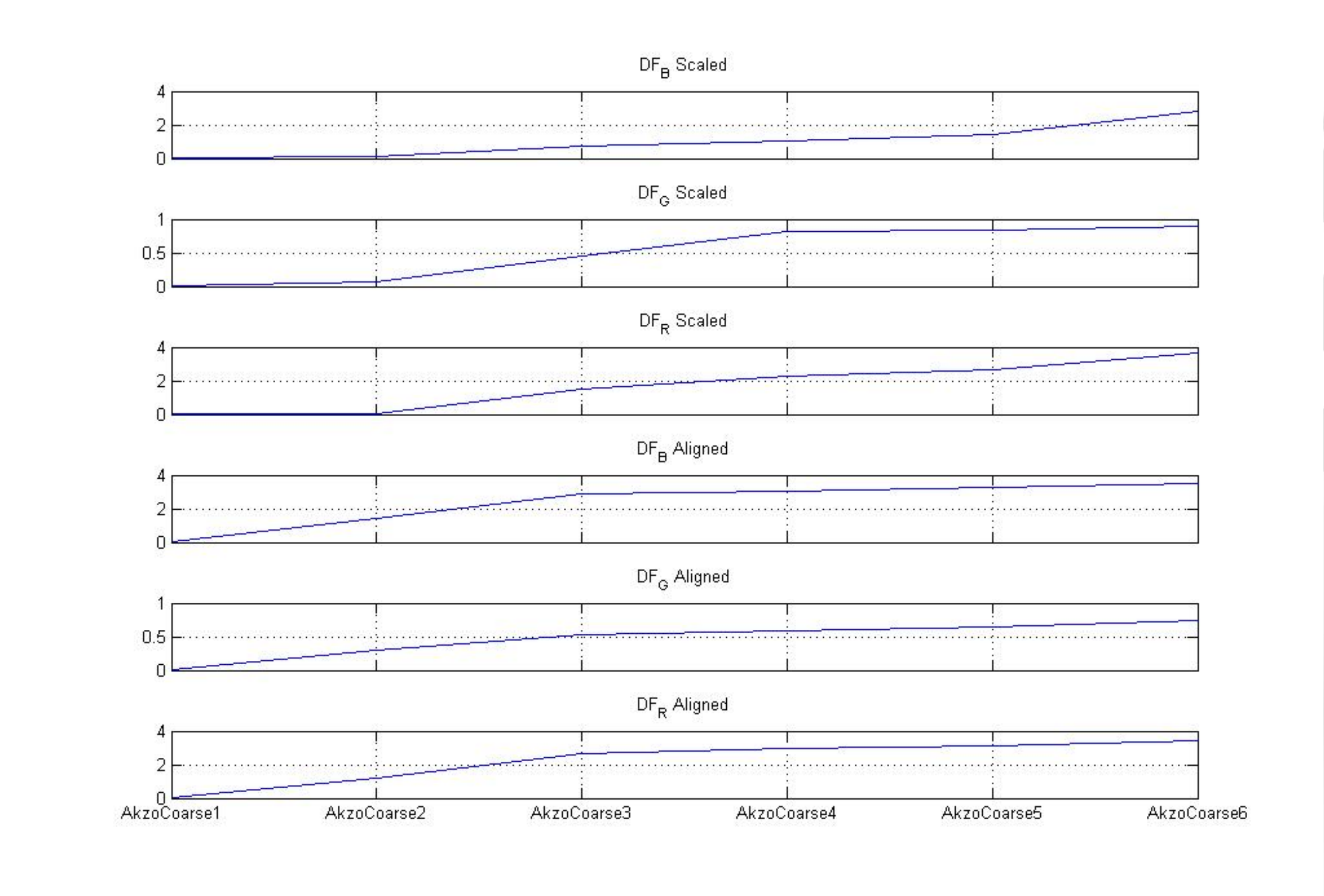


- Akzo Coarseness Index identification Swatch
- xDNA print



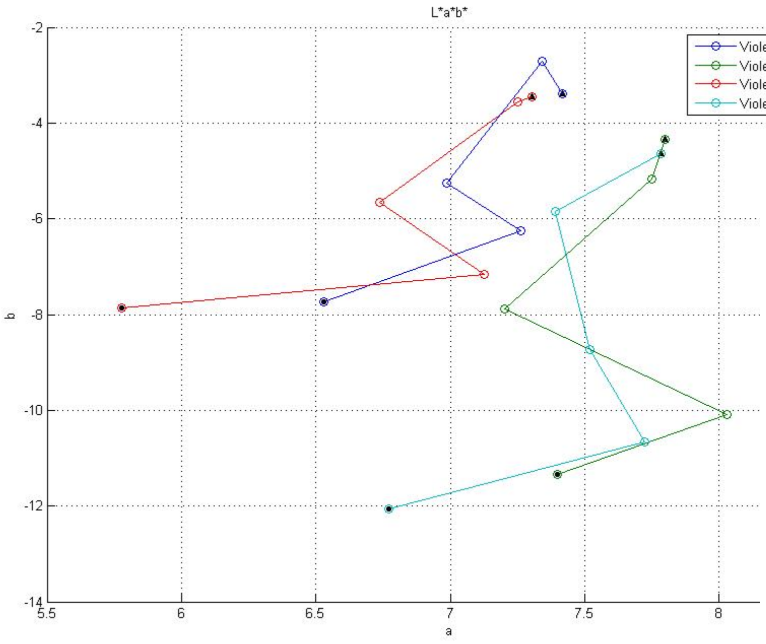


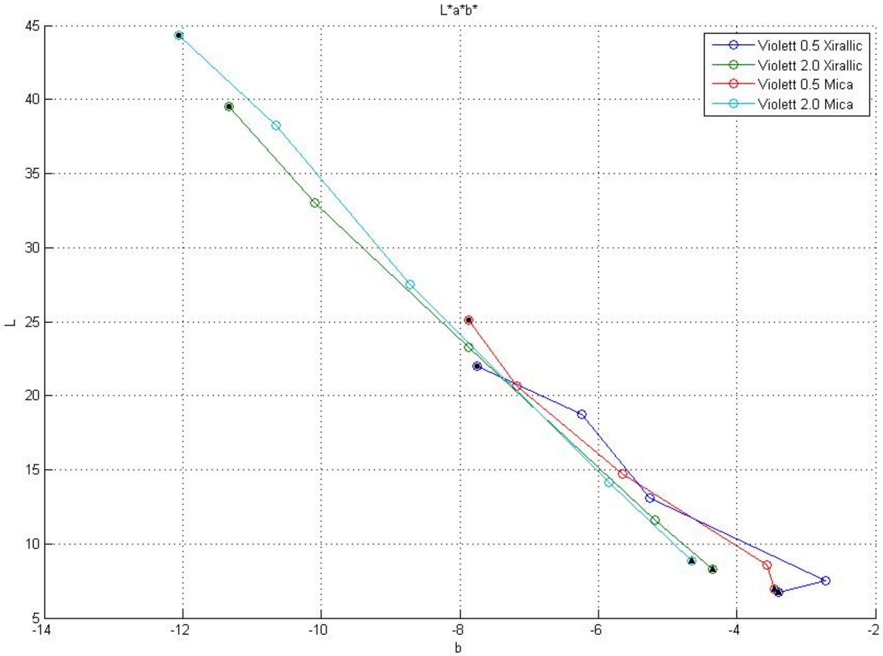
- Akzo Coarseness Index identification Swatch
- dF perceptual result



Mica versus Xirallic

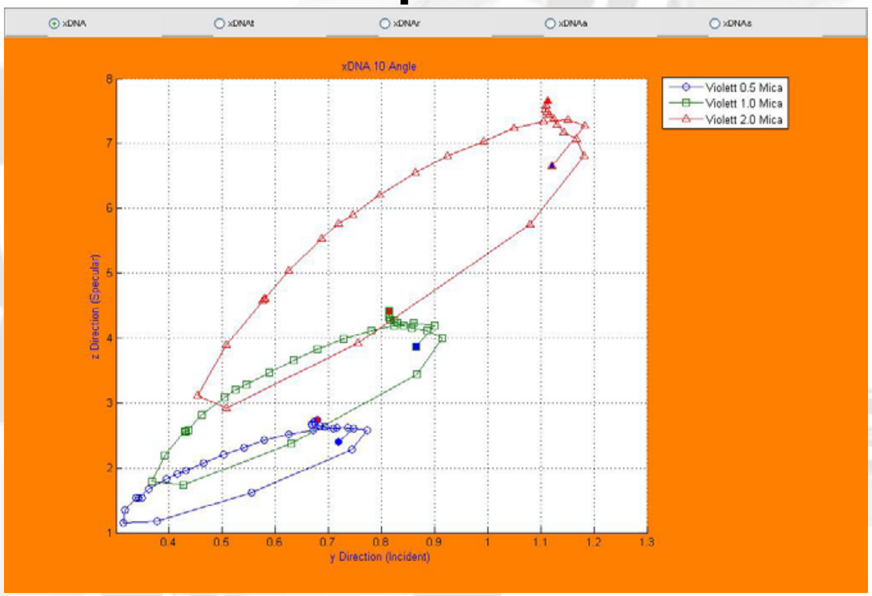
- Traditional 5 angle MA68II + -15 degree angle
- Difficult to discern in color space or with camera

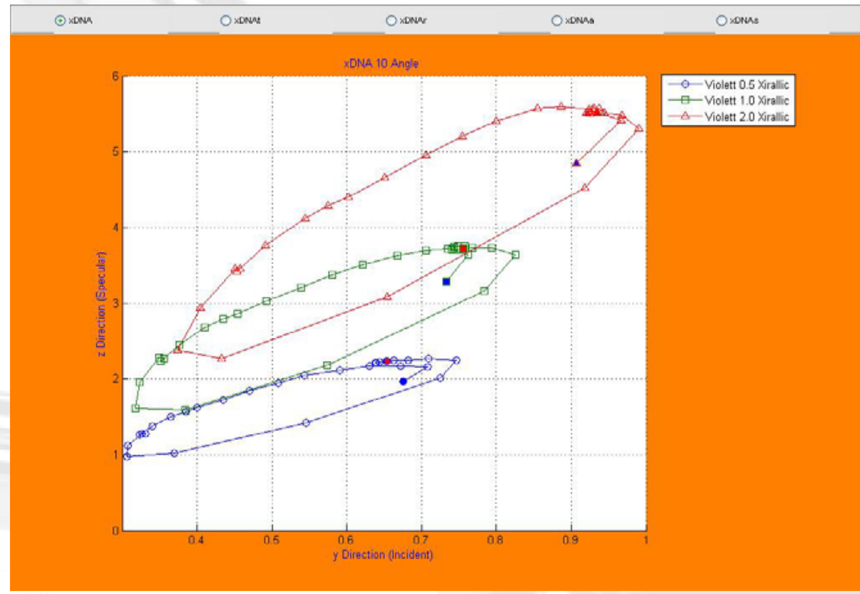


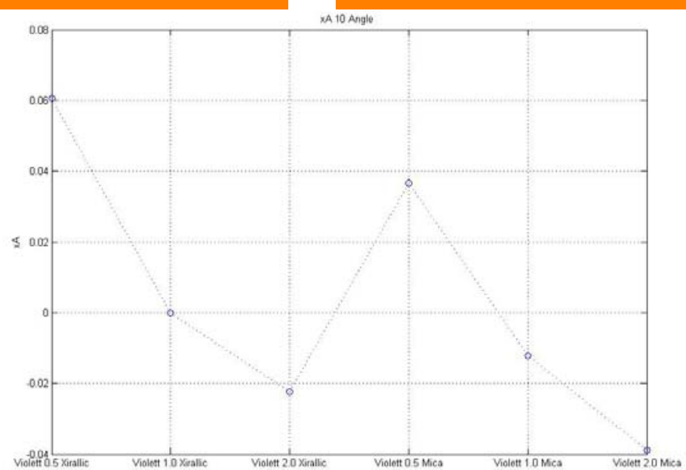


Mica versus Xirallic

- DNA print

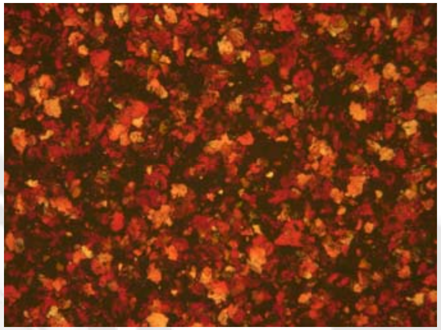


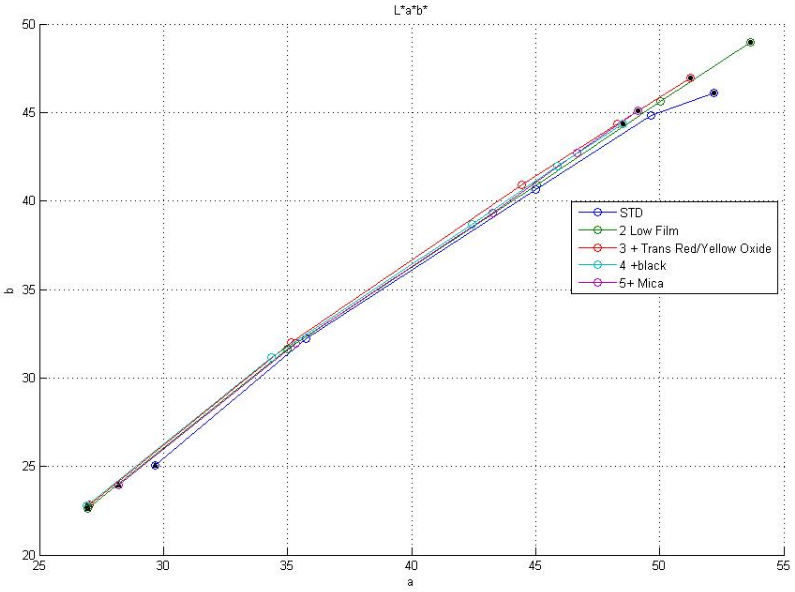


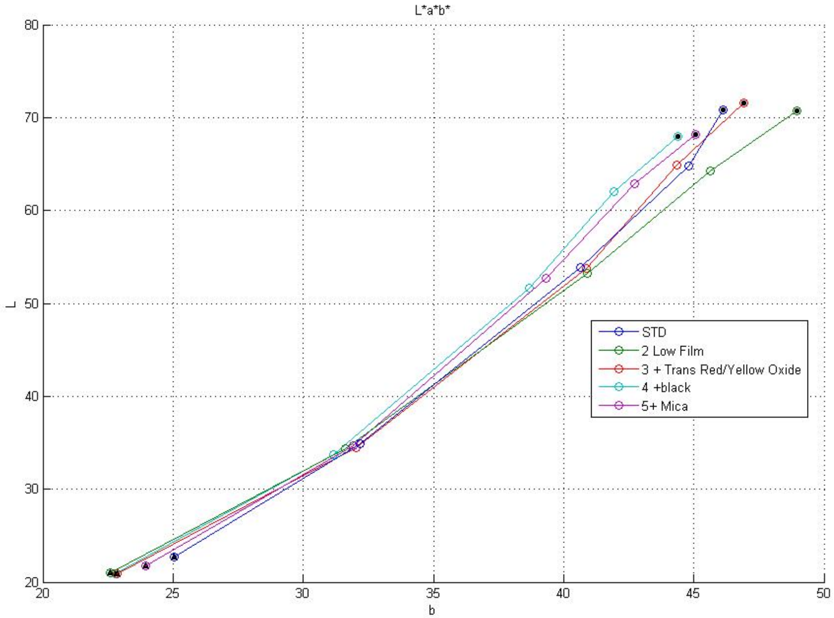


Refinish Formulation

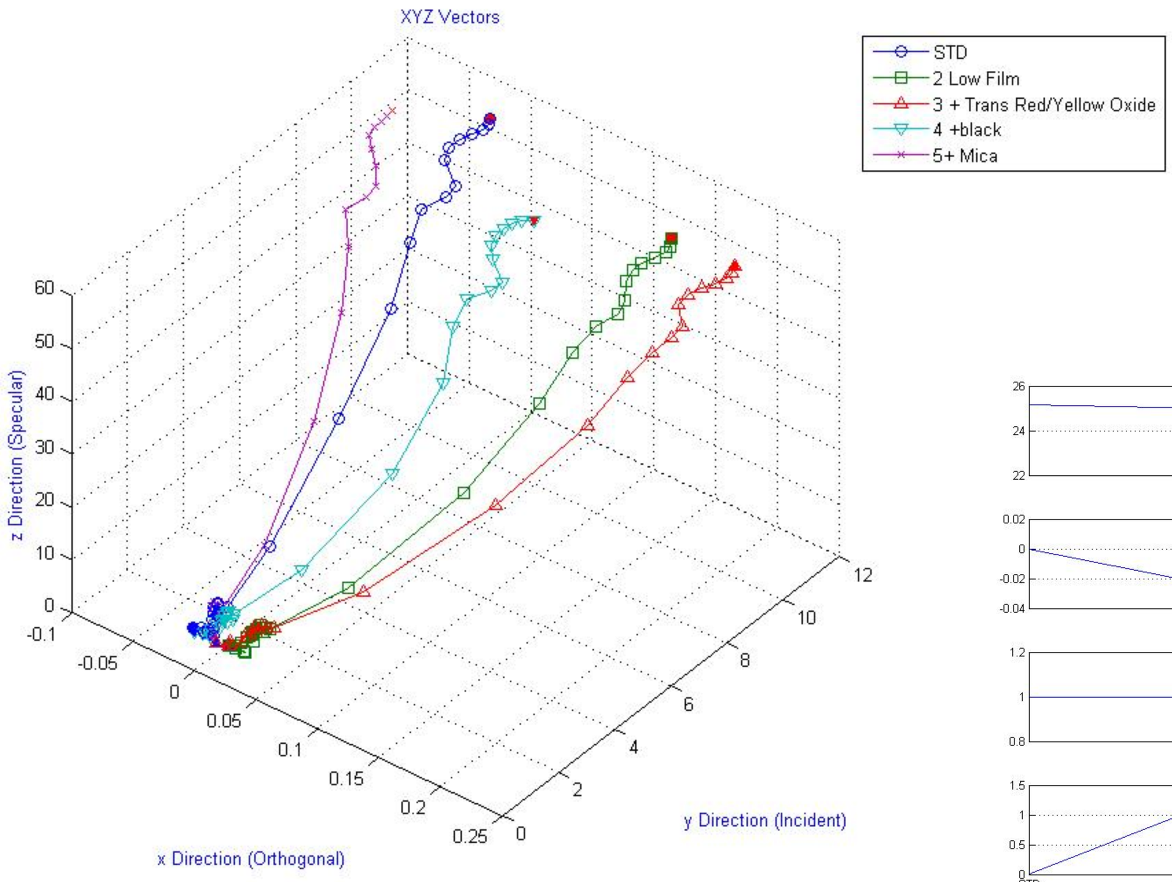
- Traditional 5 angle MA68II + -15 degree angle
- Difficult to pick best match in color space

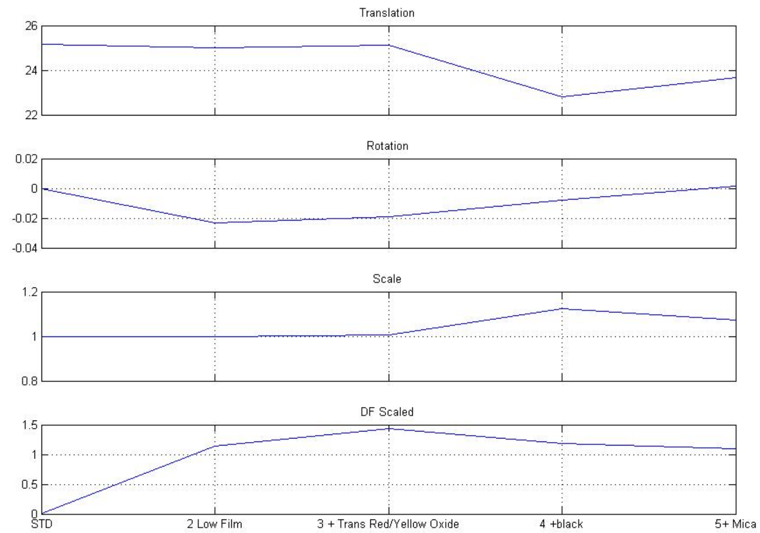




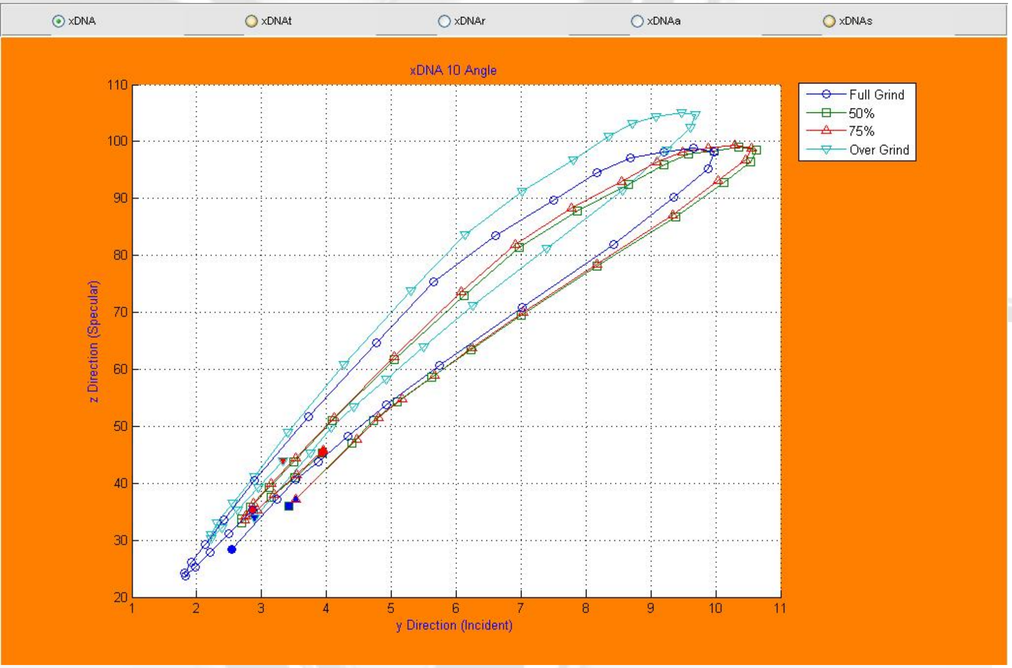


- DNA print

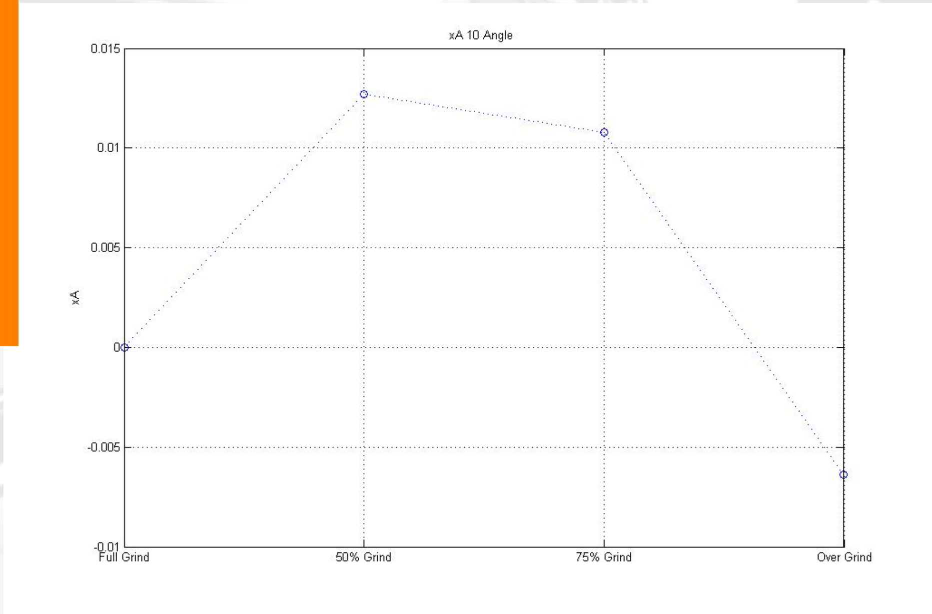

XYZ Vectors
STD
2 Low Film
3 + Trans Red/Yellow Oxide
4 +black
5+ Mica
z Direction (Specular)
60
50
40
30
20
10
0
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
x Direction (Orthogonal)
0
2
4
6
8
10
12
y Direction (Incident)


Translation
26
24
22
Rotation
0.02
0
-0.02
-0.04
Scale
1.2
1
0.8
DF Scaled
1.5
1
0.5
0
STD
2 Low Film
3 + Trans Red/Yellow Oxide
4 +black
5+ Mica

- Green DOE's

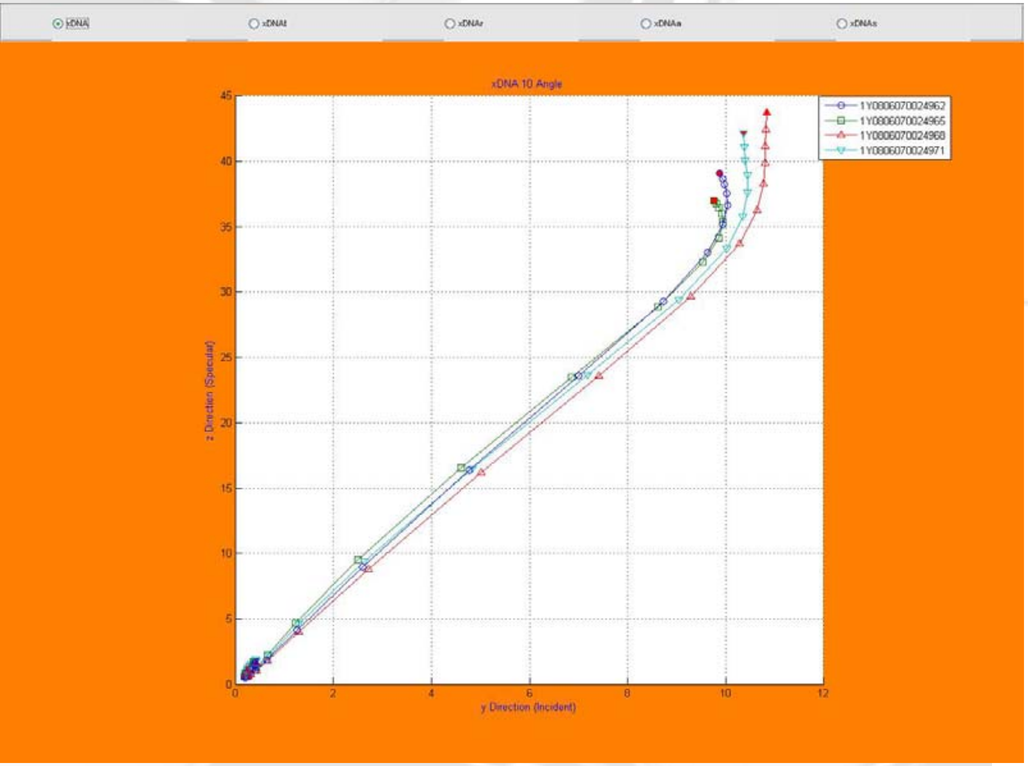


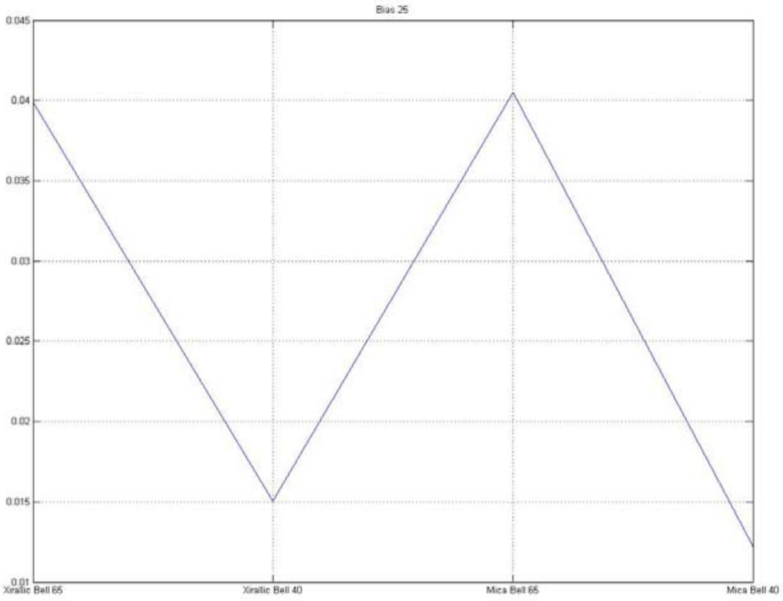
xDNA
xDNAt
xDNAr
xDNAa
xDNAs
xDNA 10 Angle
z Direction (Specular)
y Direction (Incident)
Full Grind
50%
75%
Over Grind



xA 10 Angle
xA
Full Grind
50% Grind
75% Grind
Over Grind

- Red Mica and Xirallic from DOE’s





Status of Work

- Embodies > 4 years of work
- Thousands of panels measured
- > 20 Designs of Experiment completed
- Product is being released to production

- Next Steps
  - Continue development of metrics for signature identification

The END

- Thank You !
- Follow Up Questions:
  - Jon Nisper
  - jnisper@xrite.com