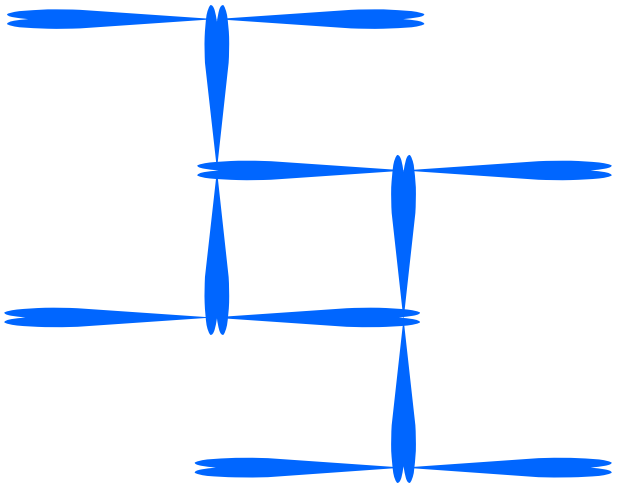


INNegRITY™

Low Dielectric Fabrics

IPC 2007, Los Angeles, CA

Outline

- Materials for low dielectric circuit boards
- Low dielectric polymers
- Low dielectric fibers & fabrics
- Composite Performance
  - Innegra™ – glass composites
  - Performance discussion & comparison
- Future Directions

Fibers for Composites

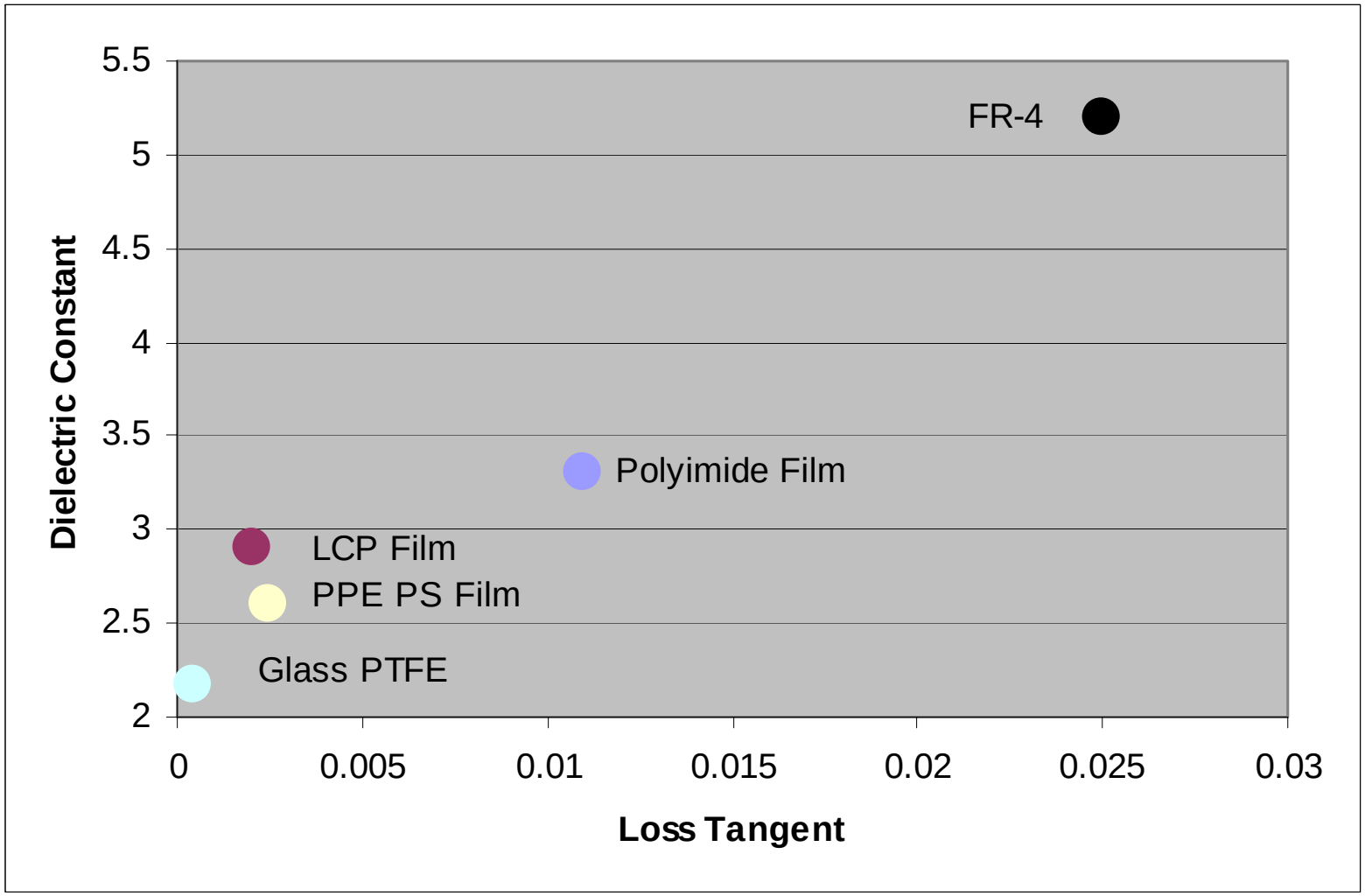
Fiber	Tenacity (g/d)	Modulus (g/d)	Dielectric Constant	Loss Tangent	Density (g/cm^3)
E Glass	5	250	6.2	0.002	2.5
S Glass	8	300	5.2	0.003	2.5
NE Glass			4.6	0.0007	
D Glass		200	4.0	0.0026	2.14
Quartz	25	370	3.7	0.0001	2.2
HMPP	10	200	2.3	0.0002	0.9
Aramid	23	950	4.5	0.019	1.4
UHMWPE	30	1400	2.3	0.0005	0.96
Carbon	11	3300	***	***	1.8

Low Dielectric Circuit Board Materials

Property	Units	PPE PS film[1]	Polyimide film[2]	Glass PTFE[3]	LCP film[4]	FR-4	Proposed Innovation
Dielectric Constant		2.6	3.3	2.17	2.9	5.2	2.8
Loss Tangent		0.0025	0.011	0.0004	0.002	0.025	0.0009
Flex Modulus	GPa	2.6	3.8	2.1	~2	17	15
Flex Strength	MPa	114	~300	~50	~100	483	400
Tensile Strength	MPa	80	241	49	120	345	300
Density	g/cm^3	1.08		2.23	1.4	1.82	1.2

[1] http://www.sheldahl.com/Product/TMComClad.htm
[2] http://www.sheldahl.com/Product/TMNovaClad.htm
[3] http://www.arlon-med.com/Diclad.pdf
[4] http://www.rogerscorporation.com/acm/about_our_products.htm#3000

Commercial PCB Electricals



Low Dielectric Thermoplastic Polymers

Property	Units	PP	PPO	COC	Polyether imide
Dielectric Constant		2.3	2.69	2.35	3.15
Loss Tangent		0.0002	0.0007	0.00007	0.0015
Density	g/cm^3	0.9	1.08	1.0	1.27
Flexural Modulus	GPa	1.38	2.5	3.0	3.5
Tensile Strength	MPa	34.5	63	60	110
Thermal Cond	W/m K	0.13			0.22
Thermal Expansion	ppm/C	100	59	60	56
Melting Point	C	162	--	--	--
Glass Trans Temp	C	--	75 – 155	75 – 180	217

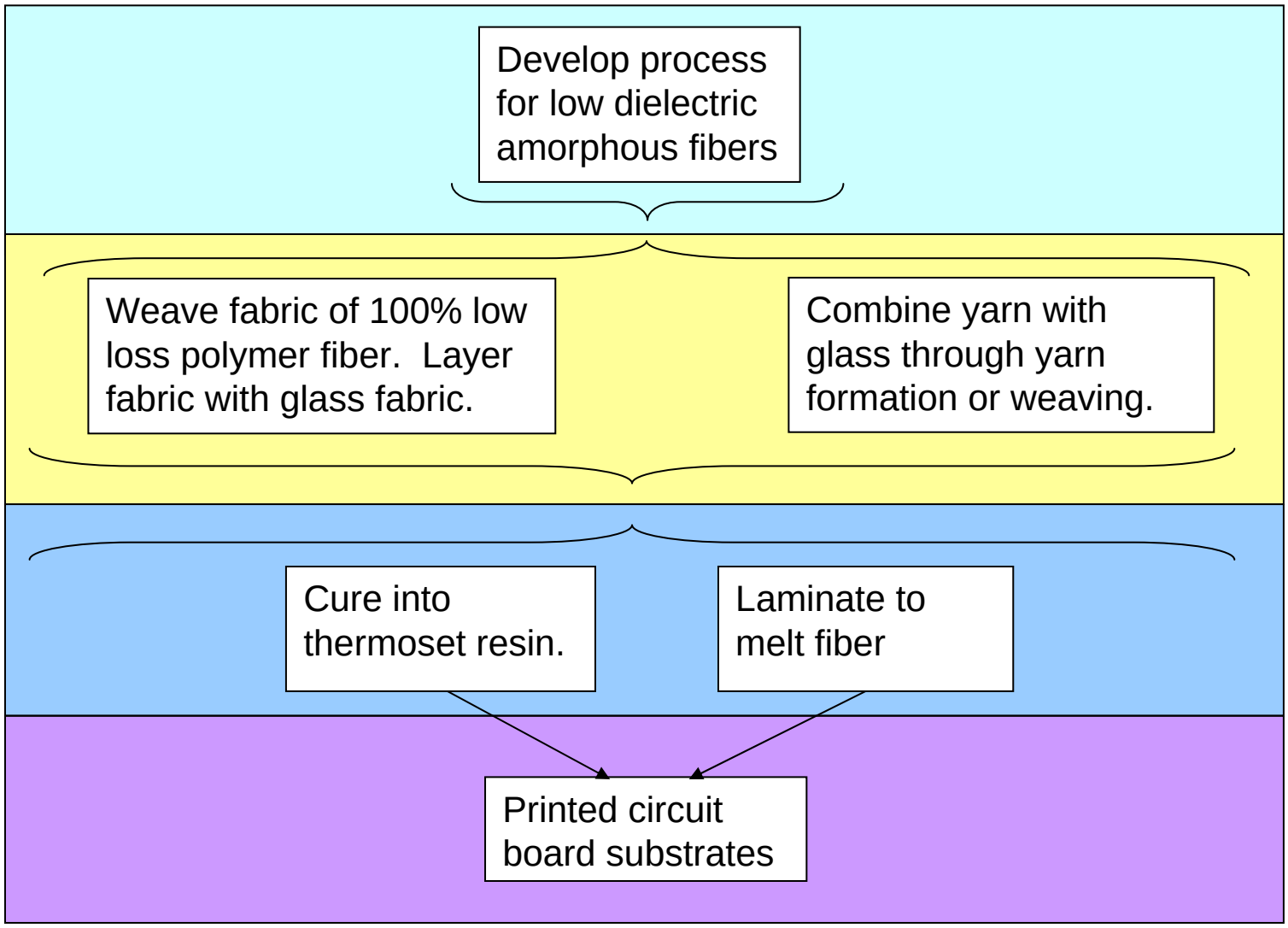
Electrical Polymers

Property		**Cyclic Olefin**	**Cyanate Ester**	**Epoxy**
Dielectric Constant		2.35	2.76	3.57
Loss Tangent		0.00007	0.006	0.021
Density	g/cm^3	1.02	1.21	1.2
Tensile Modulus	MPa	3000	3300	2600
Tensile strength	MPa	58	60	60
T_g	C	170	160	170
Water absorption	%	<0.01%		0.1%

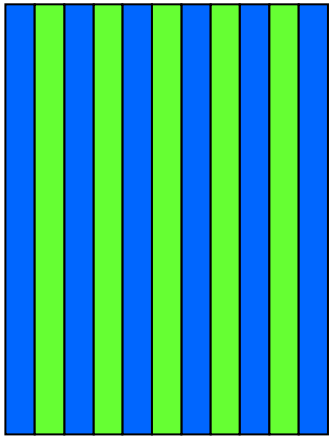
COC Yarn & Properties

- Yarn Properties
  - 2.0 g/d tenacity
  - 60 g/d modulus
  - 20% elongation
  - 3.1 denier/filament
  - 20 micron diameter

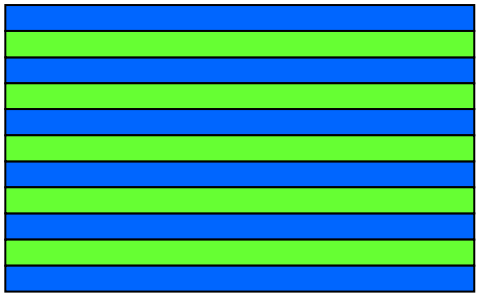
Fiber-to-PCB process



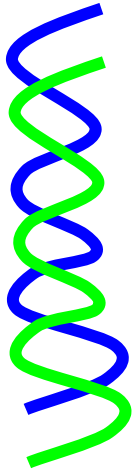
Yarn/Fabric Hybrids



A



B



C

COC

Glass

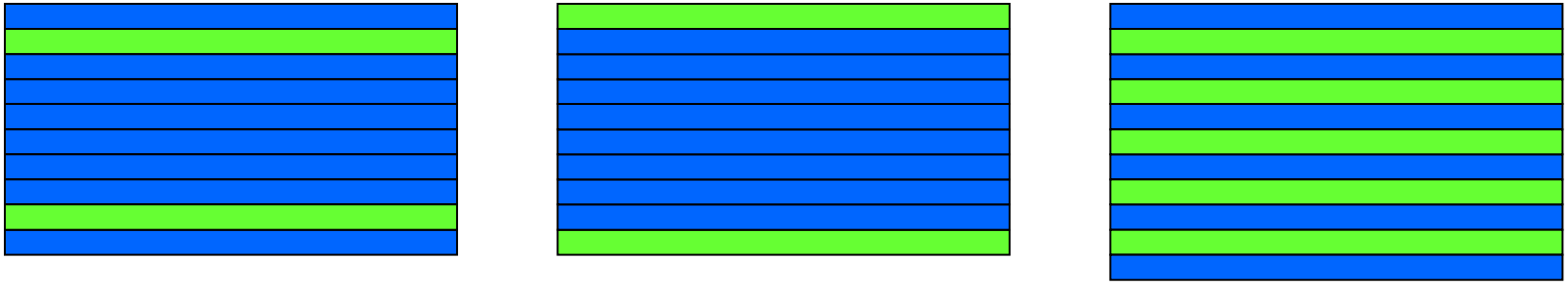
A: Alternating warp yarns

B: Alternating weft yarns

C: Hybrid twisted yarns

D: (not pictured) Glass warp, COC weft

Composite Hybrids



A B C

Innegra

Glass

1080 with Innegra™ E Weft

	"1080" with Innegra weft yarn	1080 glass fabric
% COC (vol)	25%	0%
Dielectric Constant	3.52	4.65
Loss Tangent	0.018	0.021
Flexural Modulus	2764 ksi	3125 ksi
Flexural Strength	42.4 ksi	43.3 ksi
Density	1.2 g/cm^3	1.6 g/cm^3

- 60 denier yarn
- TAP Plastics Marine Grade Epoxy

1080 with Innegra™ E Weft

	Innegra weft	Innegra cabled weft	1080
% COC (vol)	25%	17%	0%
Dielectric constant	3.08	3.29	4.49
Loss tangent	0.0131	0.0125	0.0190
Flex Strength	25 kpsi	25 kpsi	29 kpsi
Tensile Strength	48 kpsi	47 kpsi	60 kpsi

- 50 denier Innegra in “Innegra weft” sample
- 50 denier Innegra/450s glass in “Innegra cabled weft” sample
- Electrical grade epoxy resin

1080 with Innegra™ E Weft

	8 Layer	18 Layer	67% Innegra Predicted
Dielectric constant	3.53	3.25	3.6
Loss tangent	0.001	0.0013	0.0007
Density (g/cm^3)	1.5	1.5	1.5
Flexural strength (MPa)	119	120	
Flexural modulus (GPa)	10.6	9.3	
Tensile strength (MPa)	178	228	
Tensile modulus (GPa)	12.4	10.9	

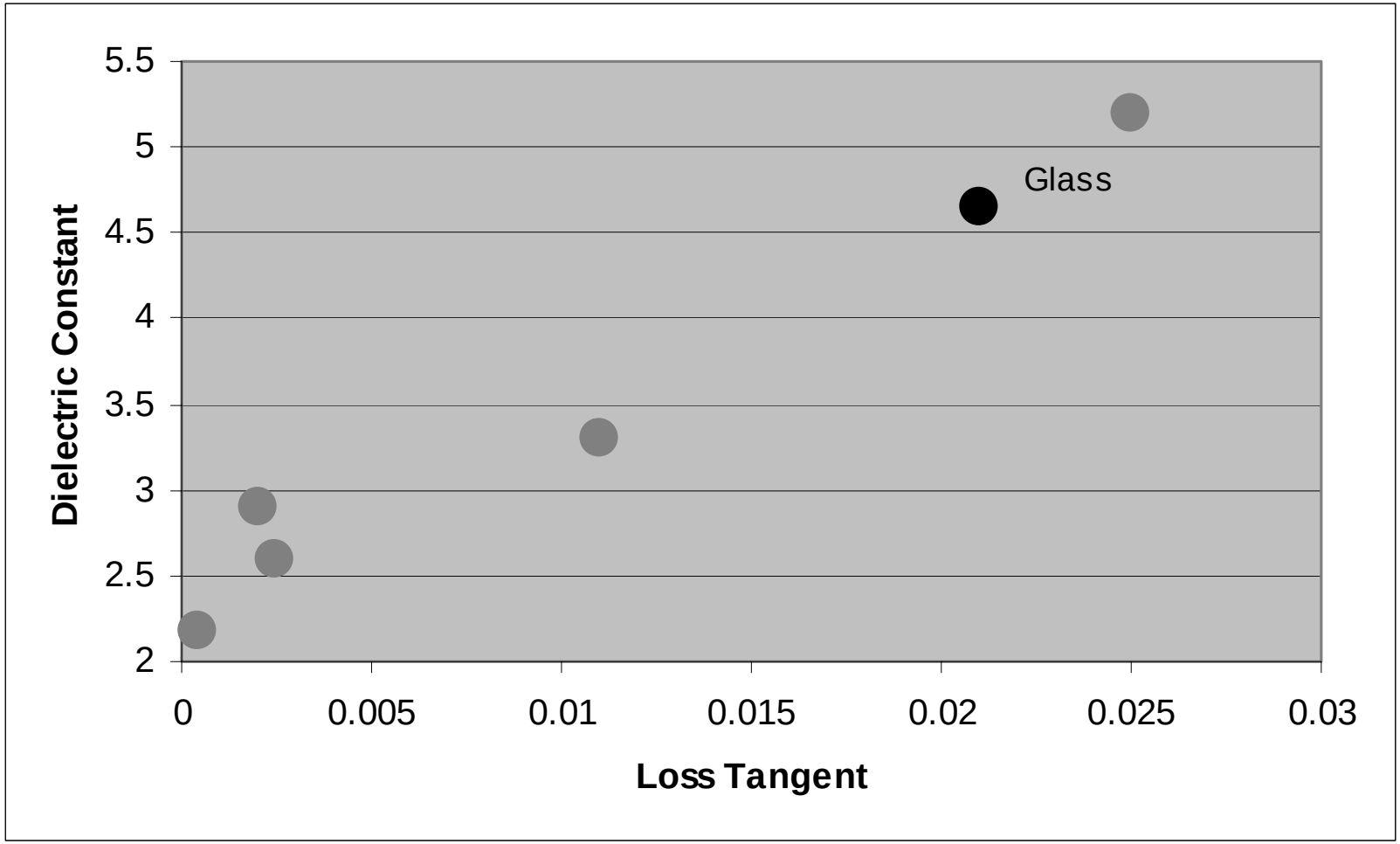
- 150 denier Innegra E/450s cabled
- Laminate molded to melt Innegra

Modified 7626 with Innegra™ E

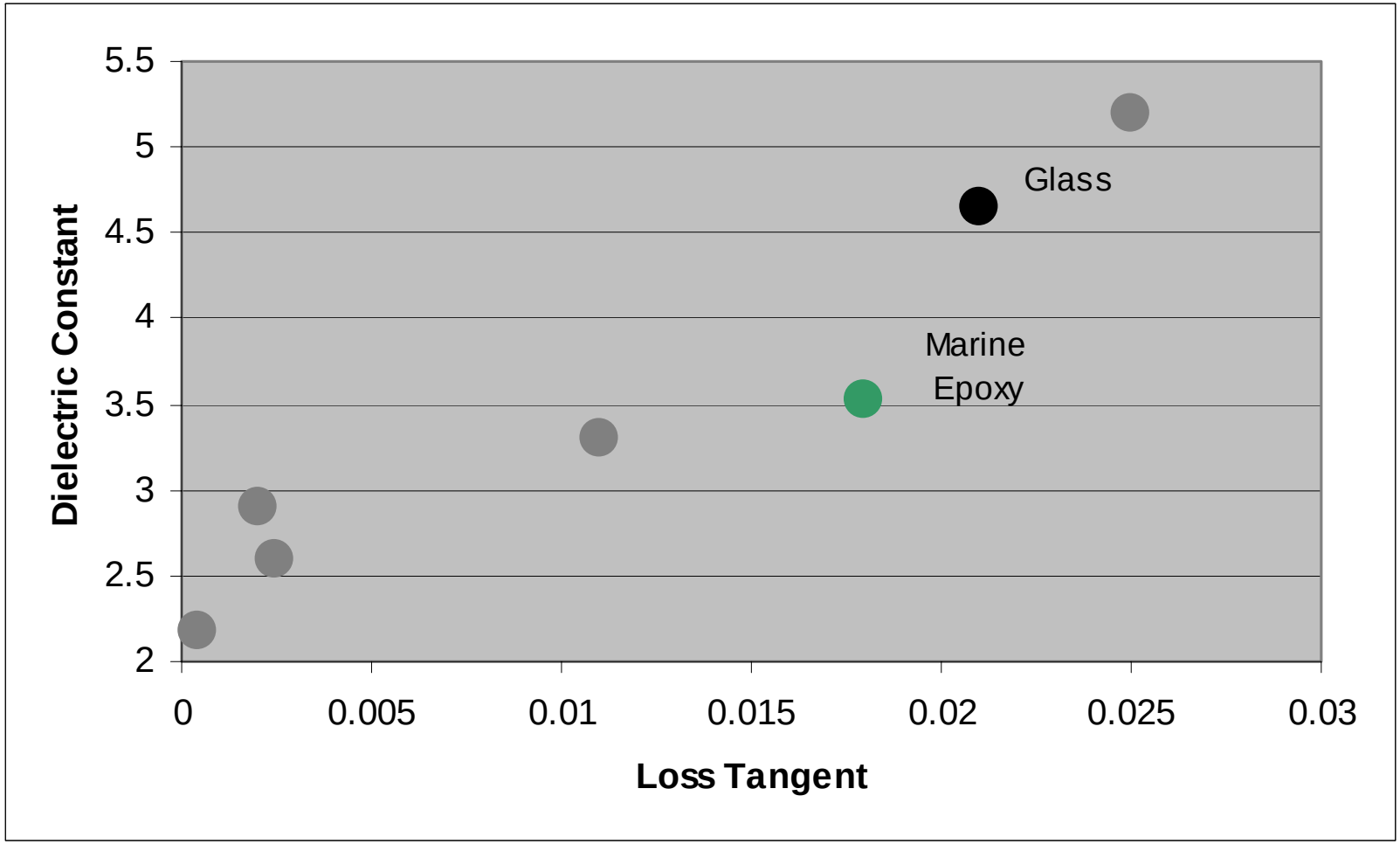
	Innegra / Arlon Resin
% COC Fiber (vol)	20%
% Low dielectric resin	60%
Dielectric constant	2.8
Loss tangent	0.0009
T_{288} (minutes)	28
Peel Strength (AR/AS) (lbs/inch)	6.8/5.6
CTE x (50-120 C)	29
CTE y (50-120 C)	28
CTE z (50-120 C)	70

- Arlon low dielectric resin

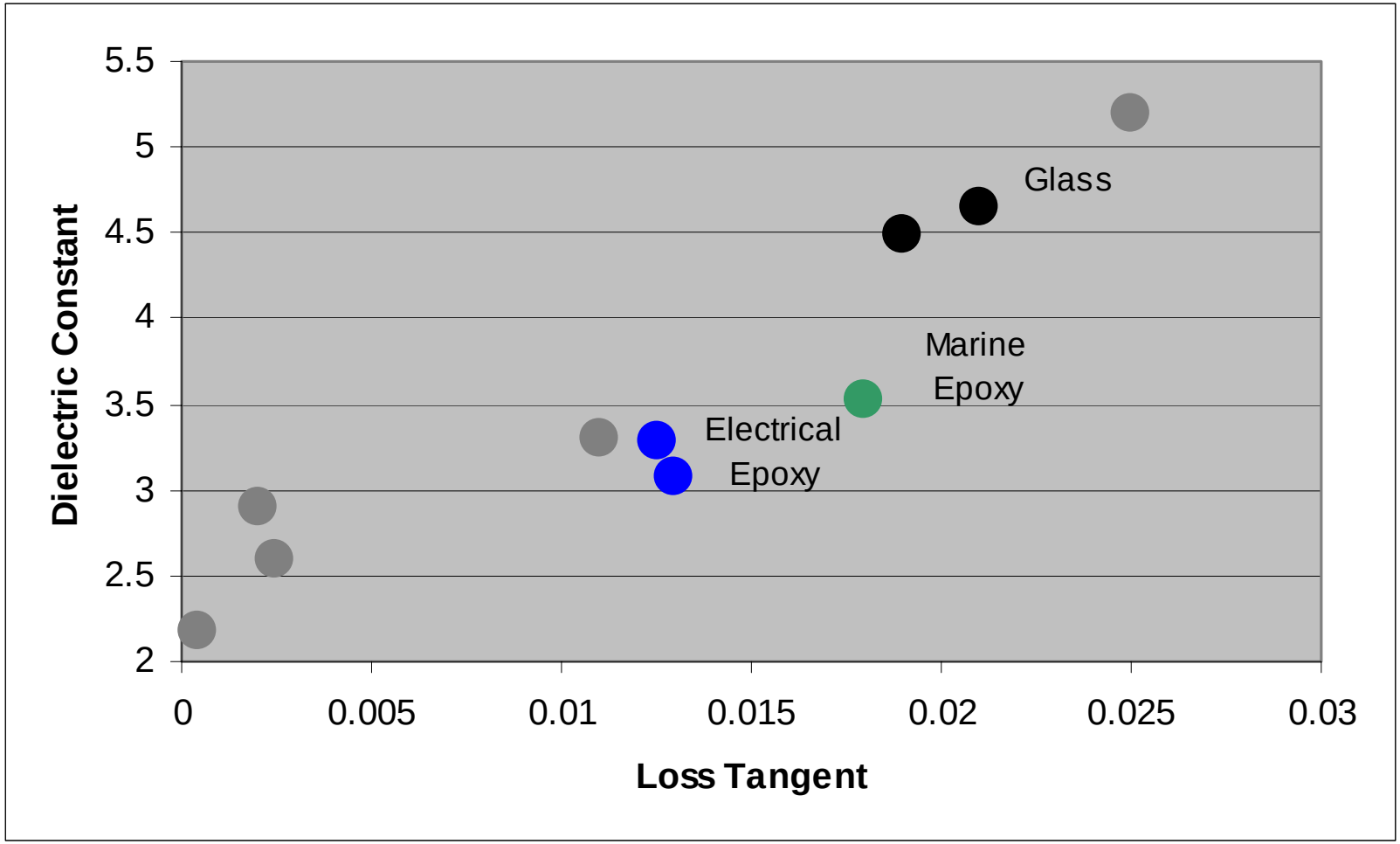
COC PCB Electricals



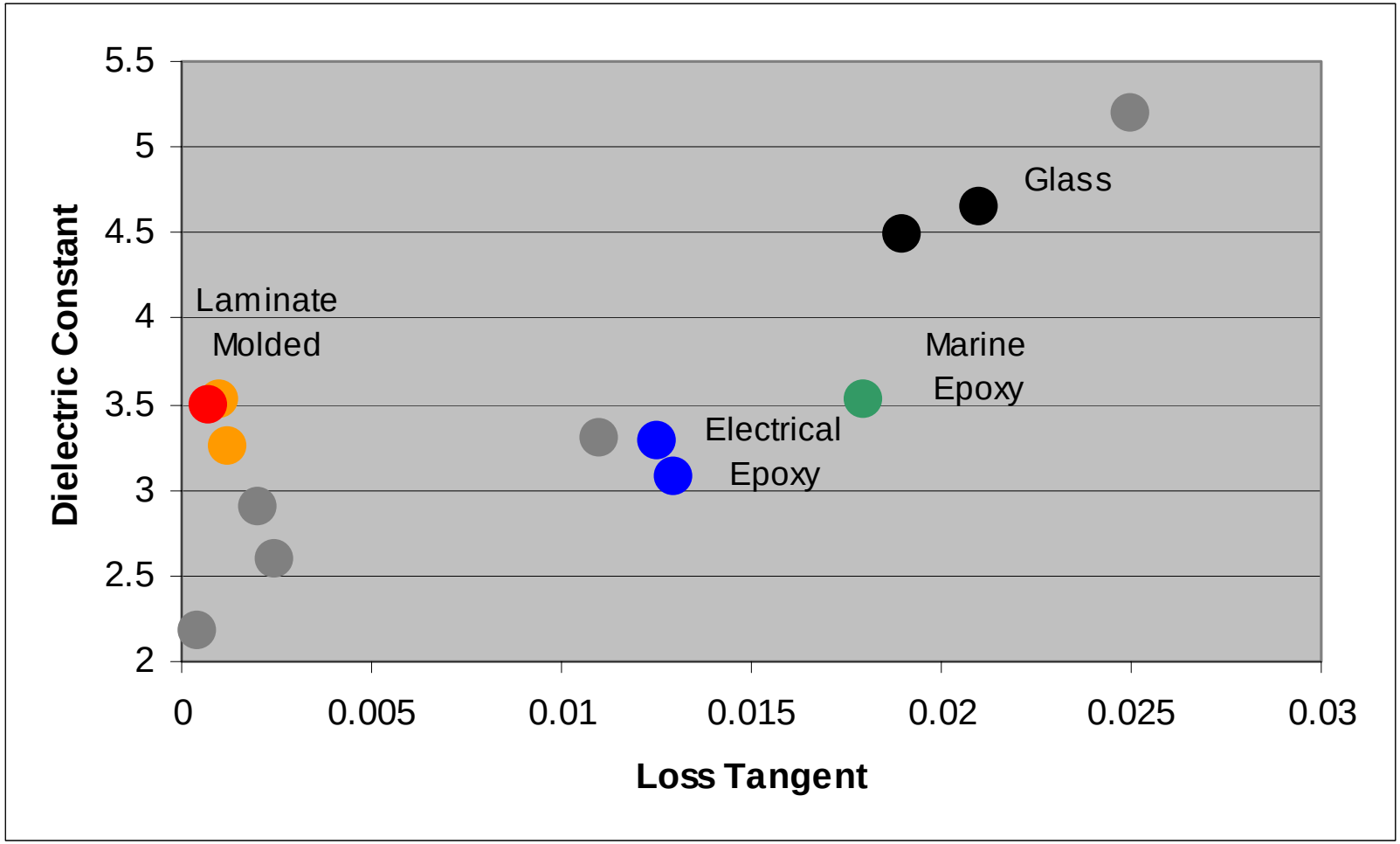
COC PCB Electricals



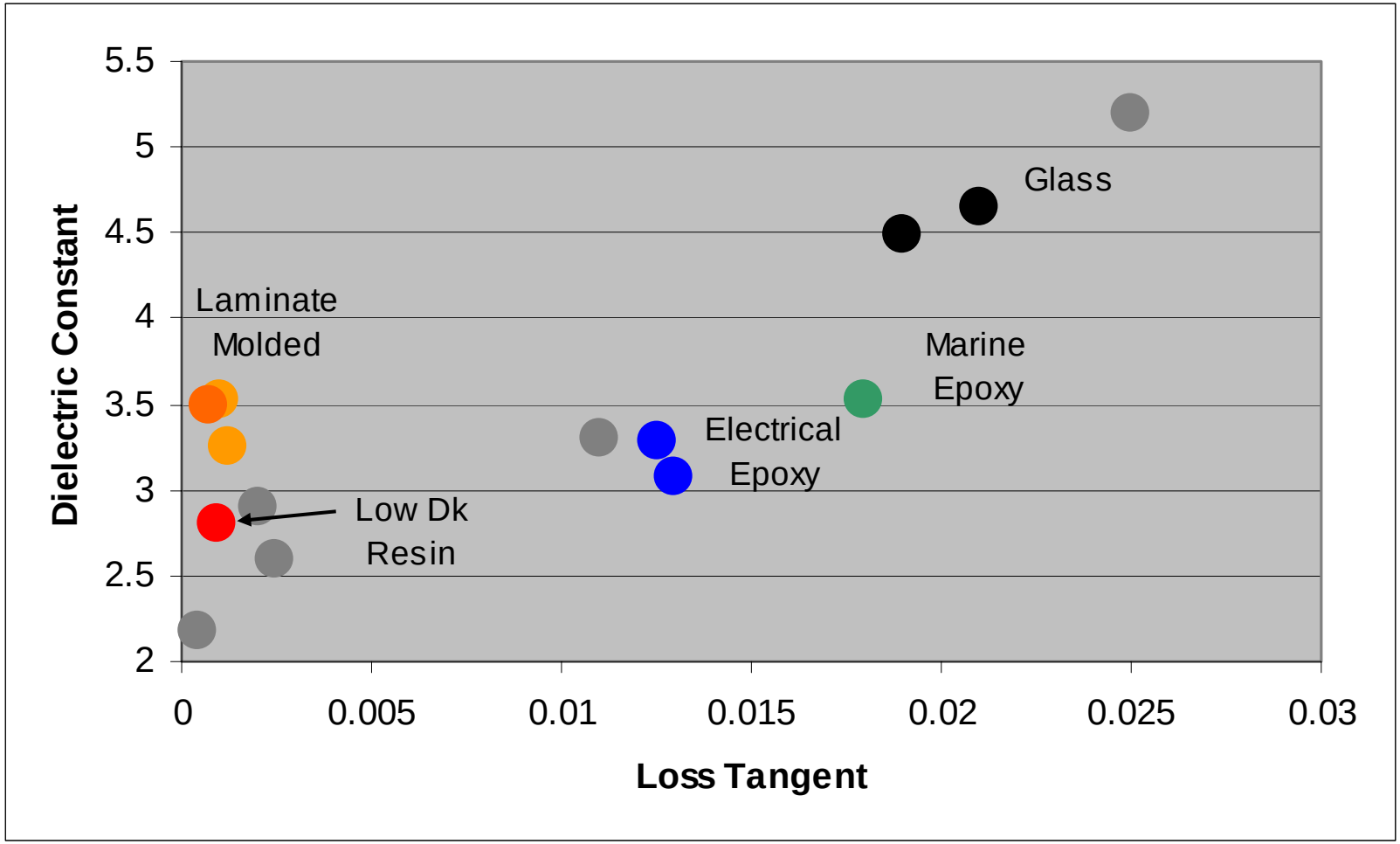
COC PCB Electricals



COC PCB Electricals

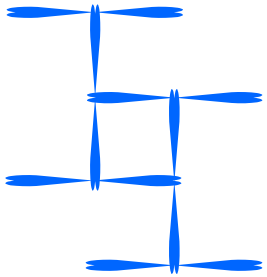


COC PCB Electricals



Future Research Directions

- Higher COC percentage fabrics
  - Further reduce glass content
  - For both thermoset and thermoplastic
- Nonwovens
  - Nondirectional
  - For both thermoset and thermoplastic
- Qualification
  - T_{288}, peel, CTE, etc on all substrate types



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