

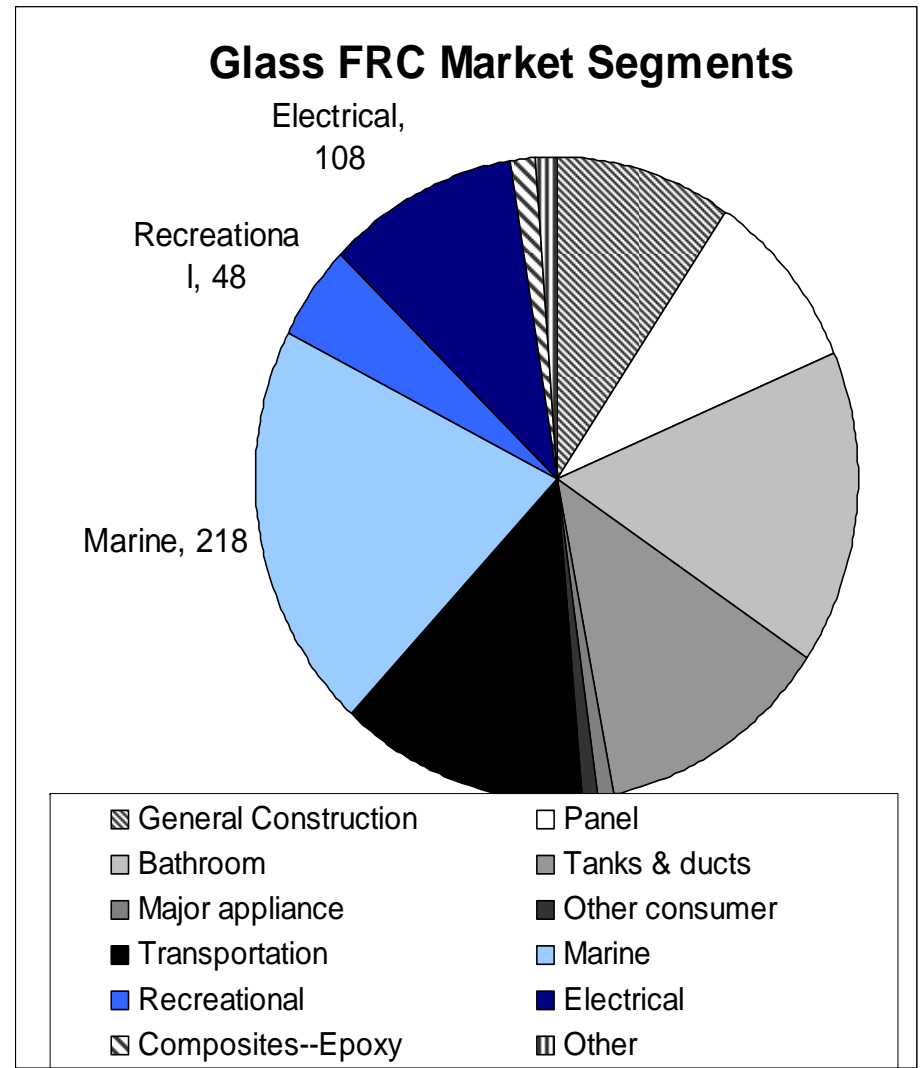
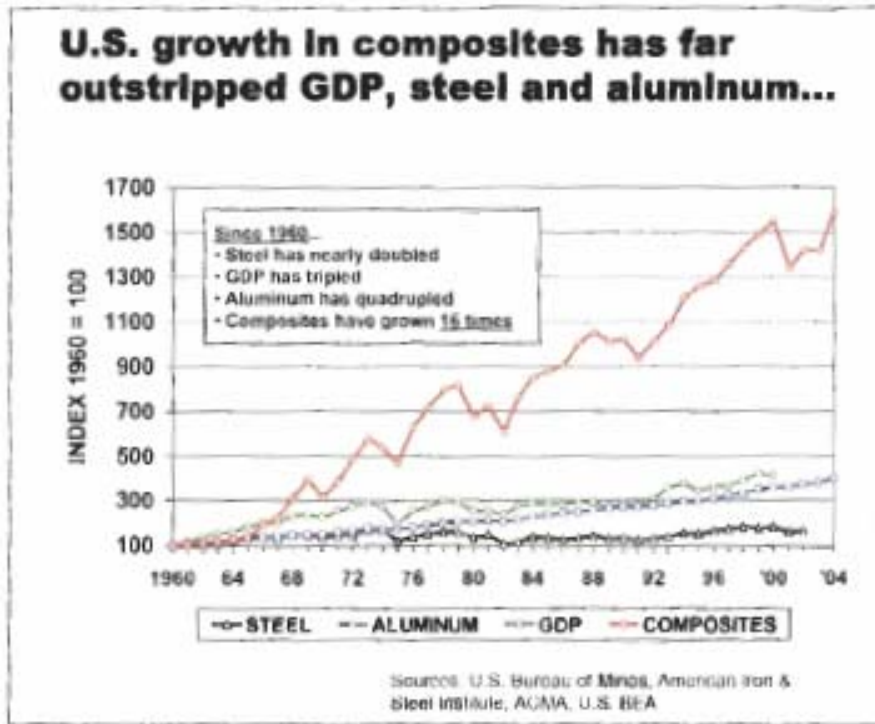


TechTextil 2008

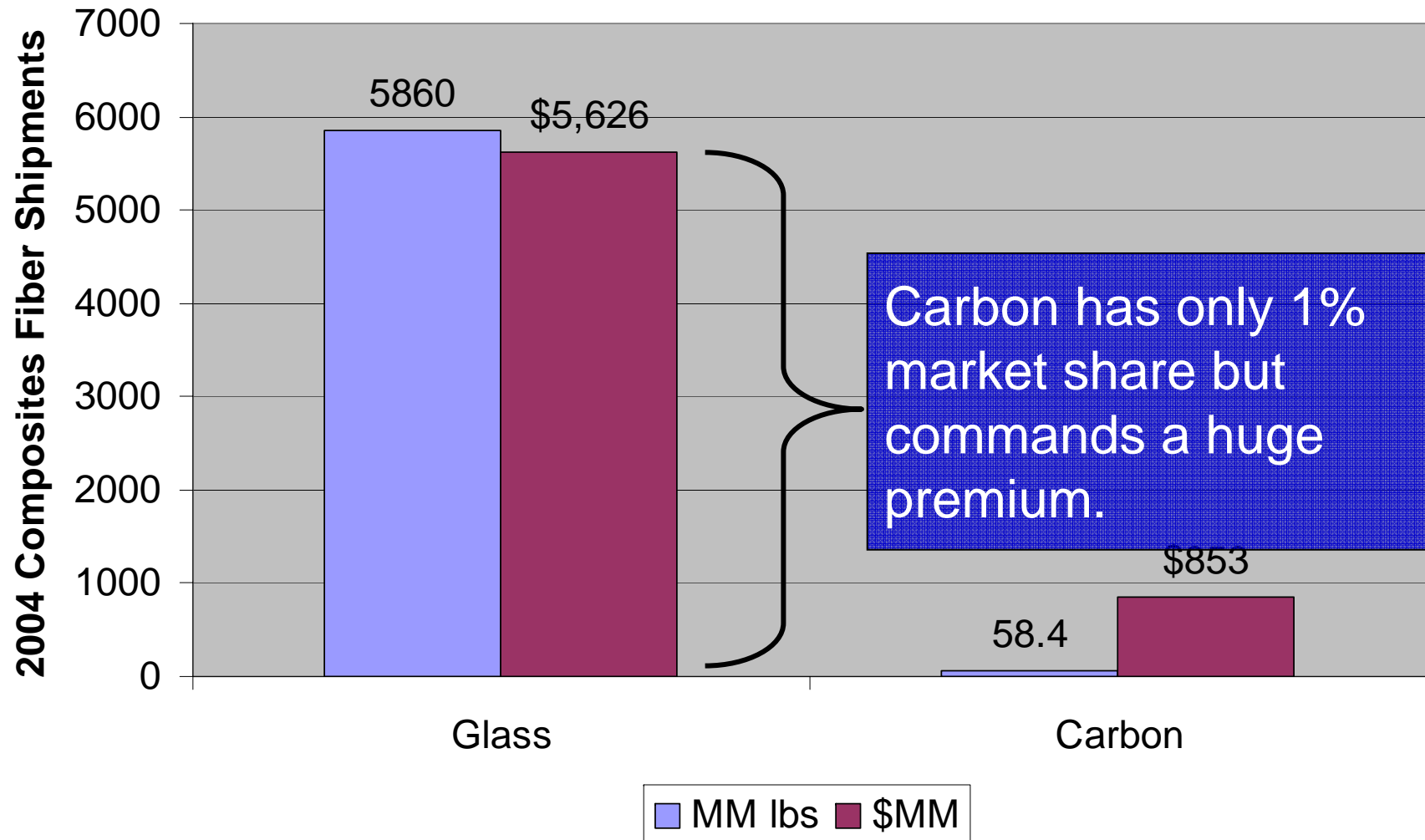
Outline

- Composite Introduction
- HMPP fiber
 - Fiber sizing
 - Fabrics
- HMPP hybrid composites
 - HMPP – glass
 - HMPP – aramids
 - HMPP – carbon
 - HMPP – quartz

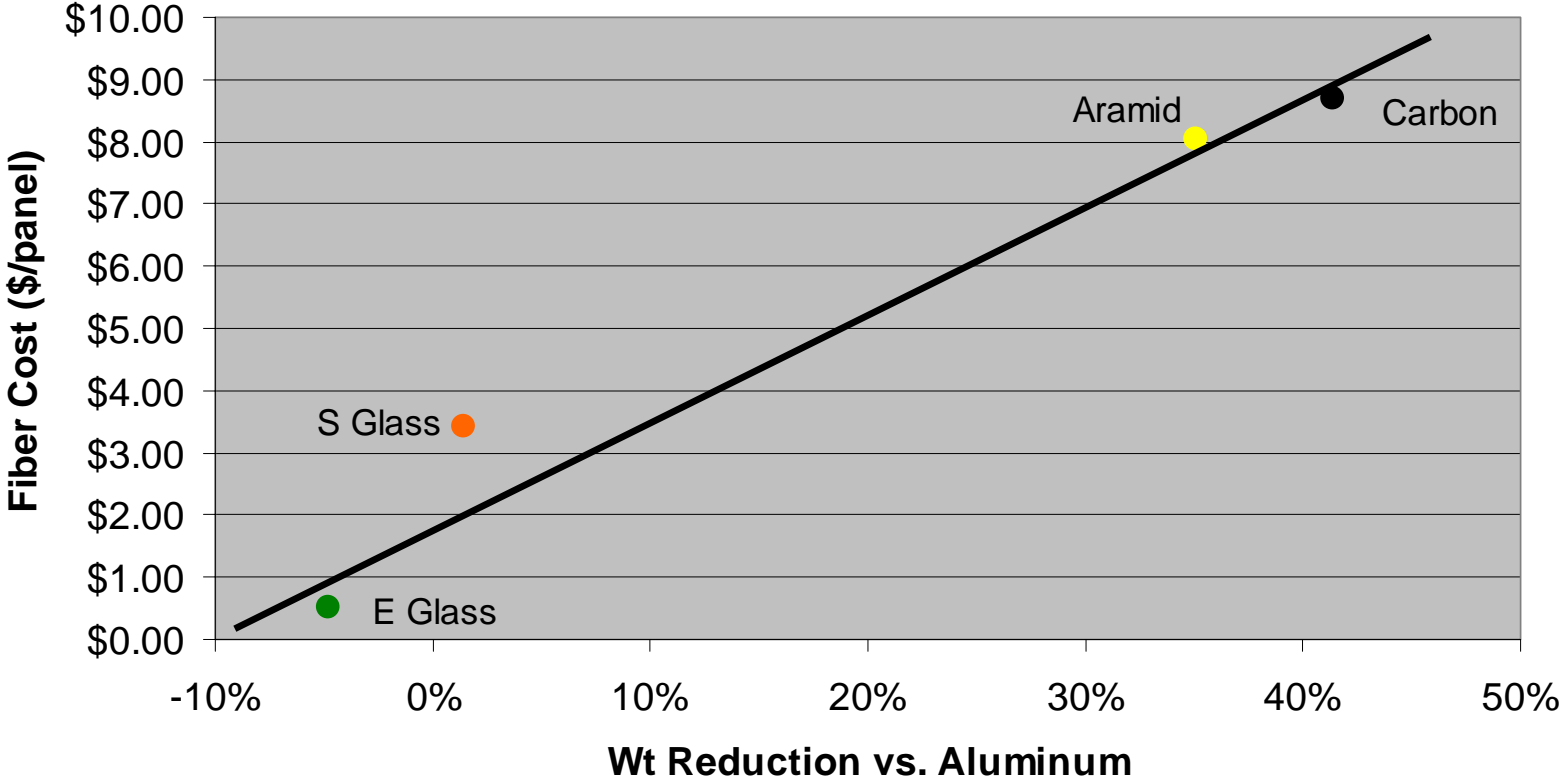
Composites Market



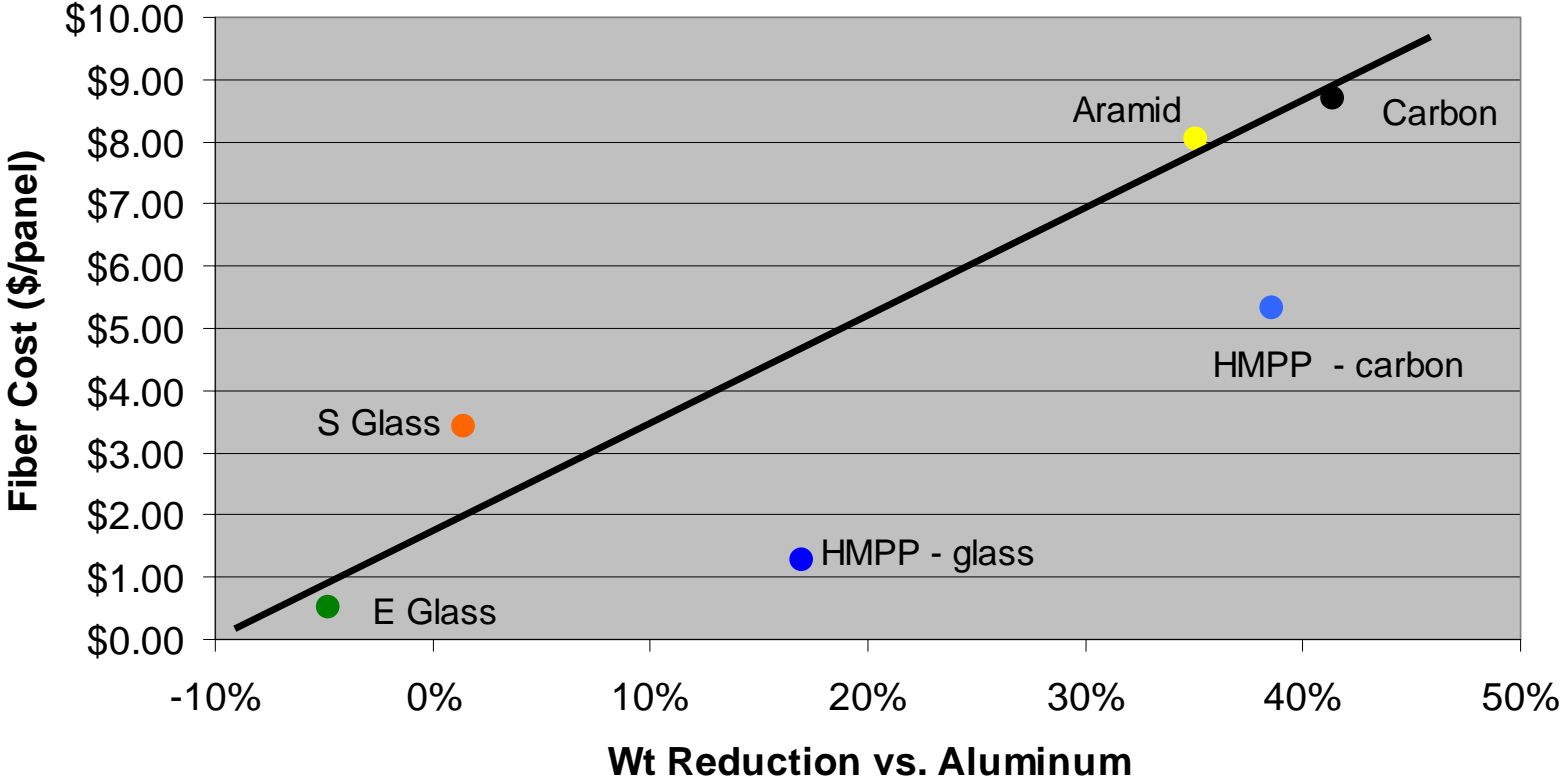
Carbon commands a premium...



HMPP fiber can fulfill the need



HMPP fiber can fulfill the need



HMPP Fiber

- Structural fiber to enhance composites
 - Light weight
 - Tough
 - Low dielectric

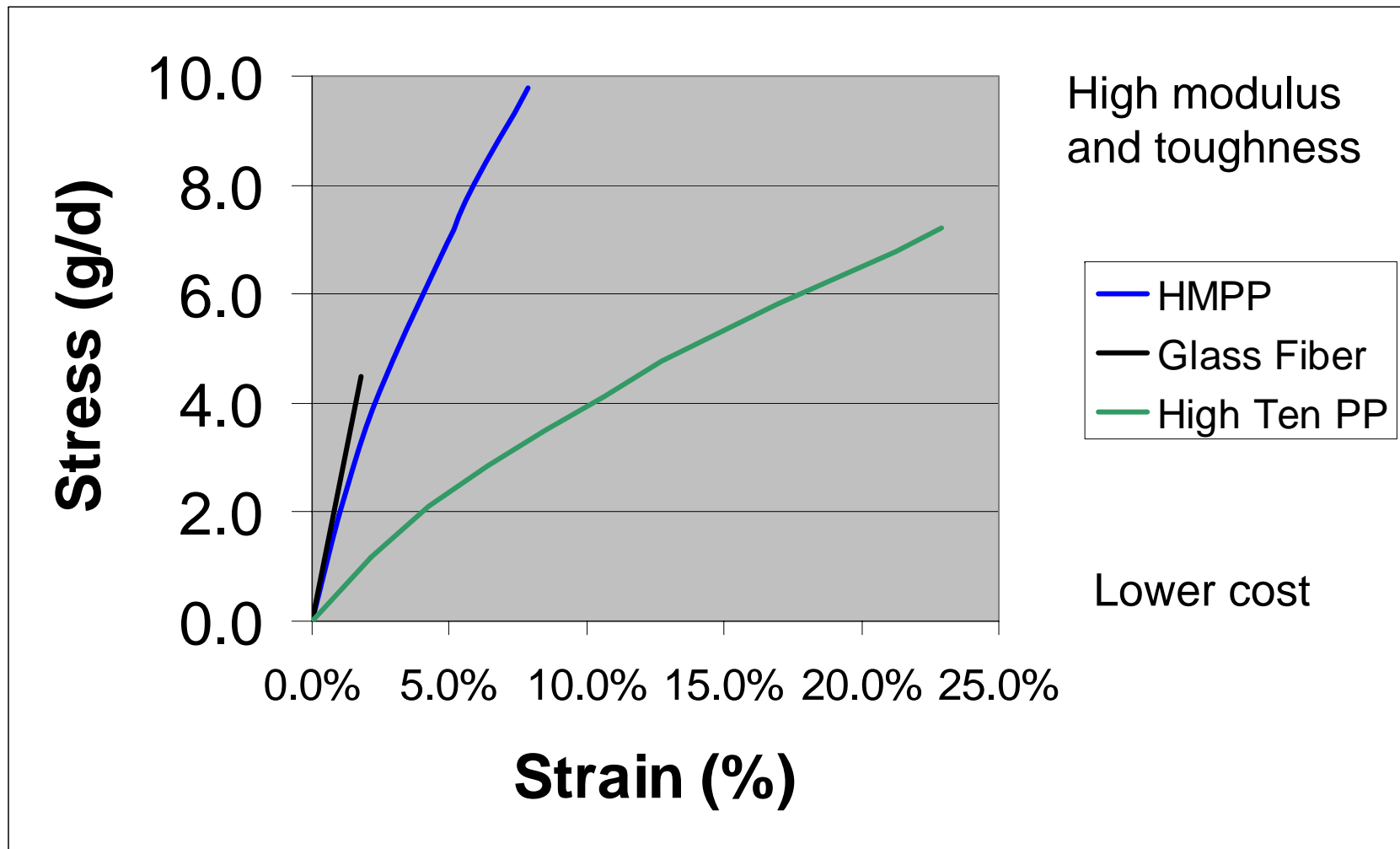


HMPP Fiber

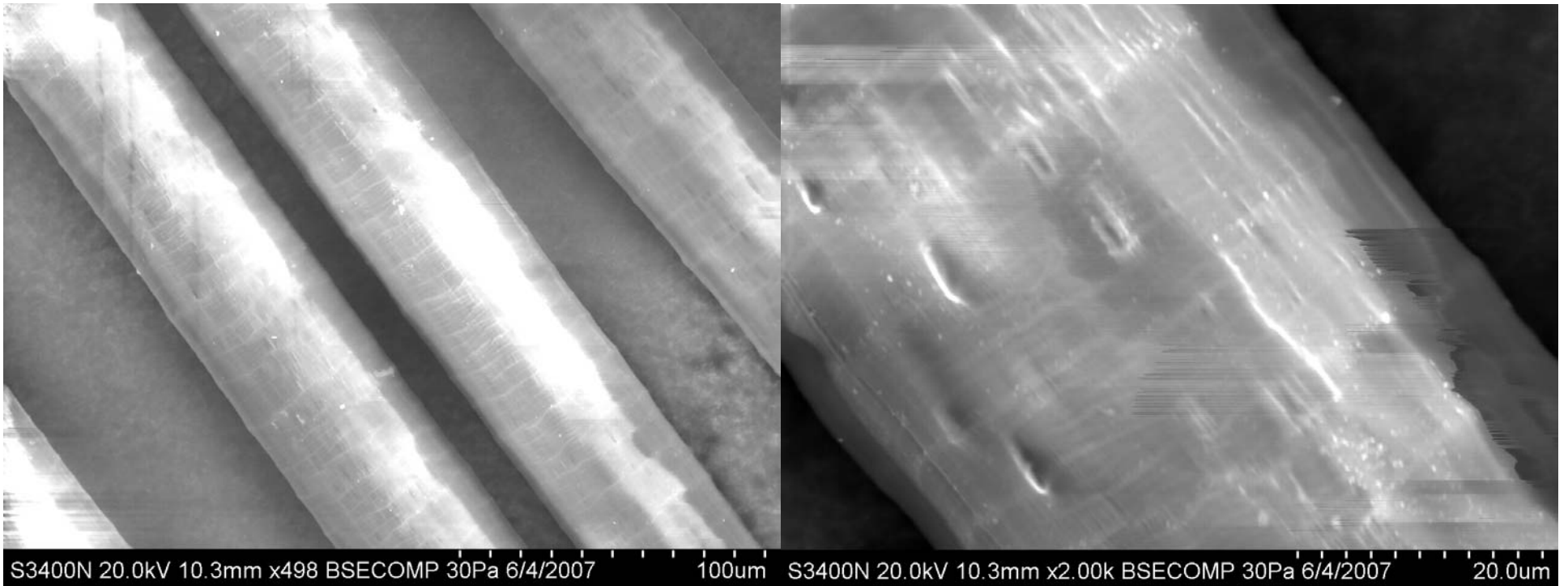
Fibers for Composites

Fiber	Tenacity (g/d)	Modulus (g/d)	Density (g/cm ³)	Toughness (g/d)	Dielectric Constant
Glass	3.5	250	2.5	0.03	6.2
HMPP	9	190	0.84	0.6	2.1
Aramid	23	950	1.4	0.3	4.5
UHMWPE	30	1400	0.97	0.7	2.3
Quartz	25	370	2.2	0.27	3.8
Carbon	11	3300	1.8	0.02	NA

HMPP Fiber Properties



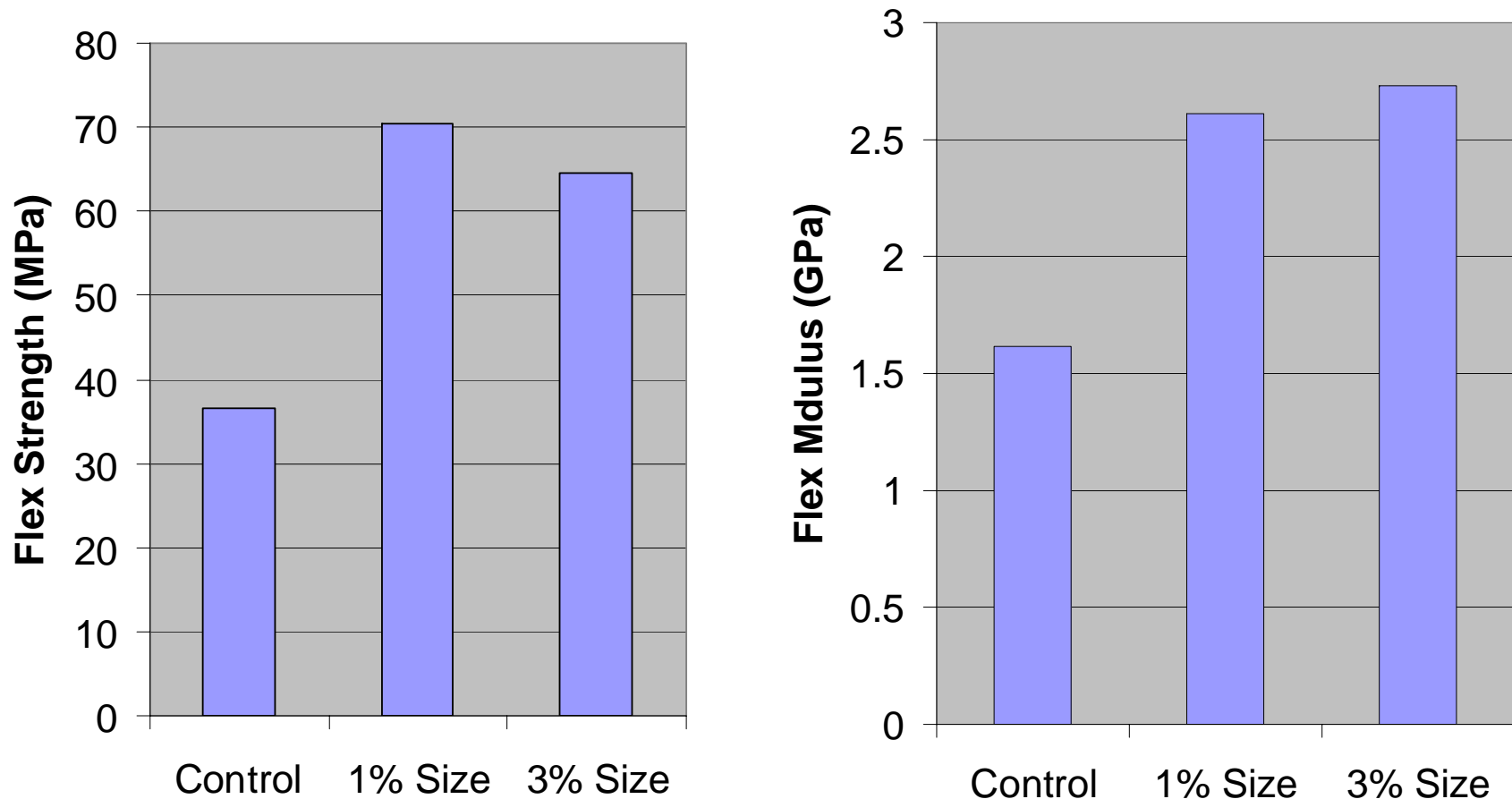
Unique Surface Characteristics



Fiber Sizing

- Needed for weaving
- Compatibilize HMPP surface with resins
 - Polyester
 - Vinyl Ester
 - Epoxy

Sized vs. Unsized Composites



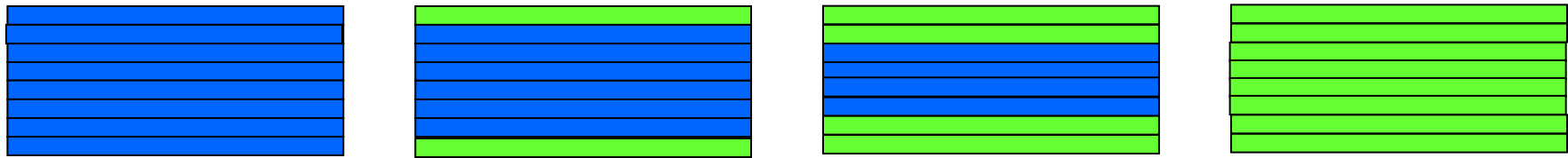
HMPP Fabrics

- HMPP
 - Woven
 - Plain weave, satin, twill
 - 3.5 – 13 ounces/sq yd
 - Stitched
 - +/- 45 multiaxial
 - 17 ounces /sq yd
- Hybrids
 - Glass – HMPP
 - Carbon – HMPP
 - Quartz – HMPP
 - Aramid – HMPP
 - Plain weaves
 - Many varieties



HMPP – Glass Hybrids

Composite Samples



A

B

C

D

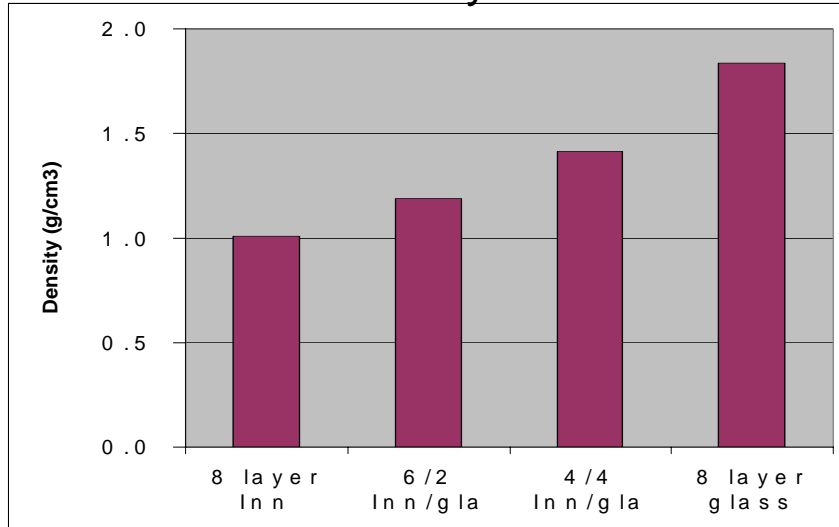
■ HMPP

■ Glass

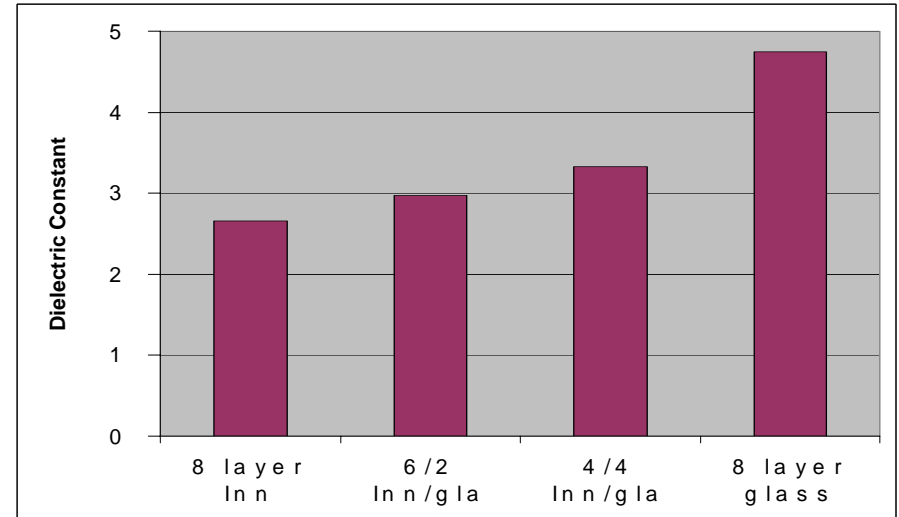
- 8 Layer composites
- Epoxy resin
- Two-sided mold (6" x 2", open ends)
- 24 hr RT cure

Composite Properties

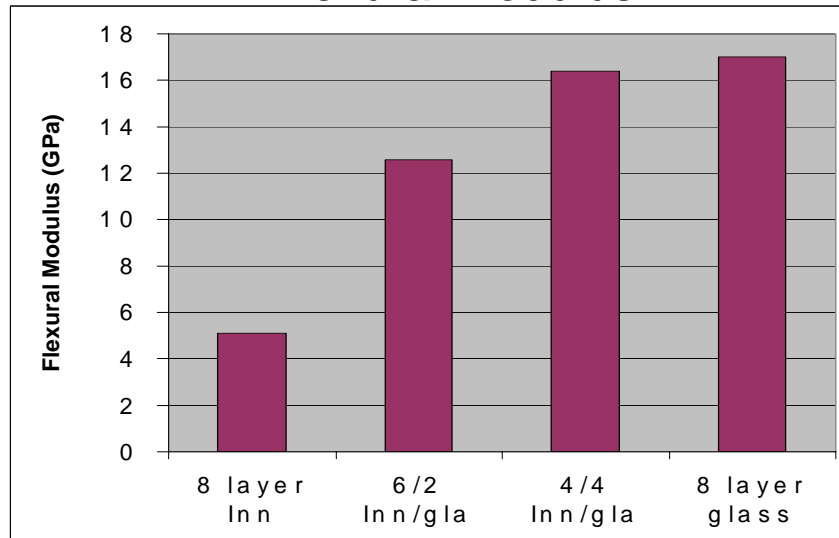
Density



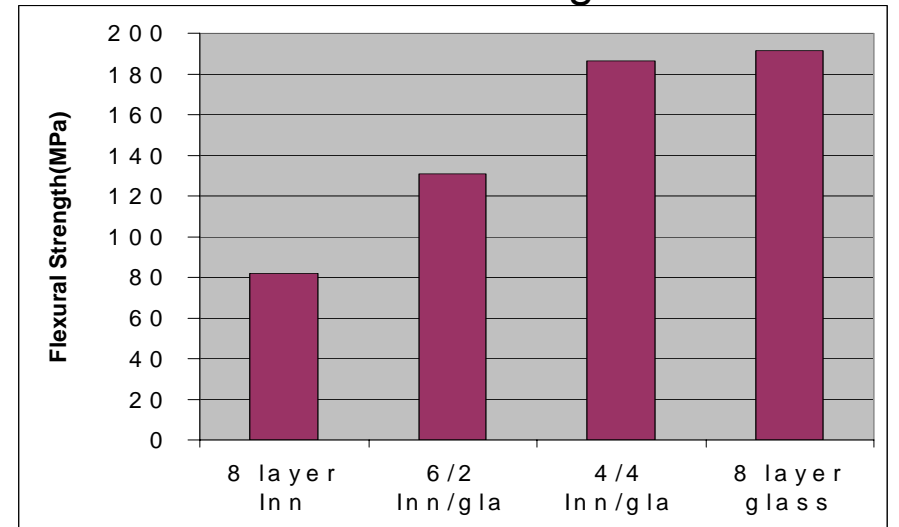
Dielectric Constant



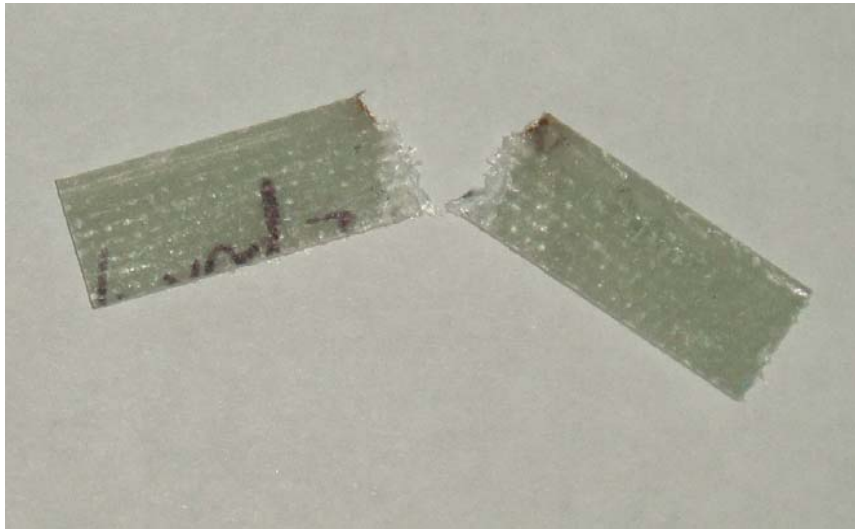
Flexural Modulus



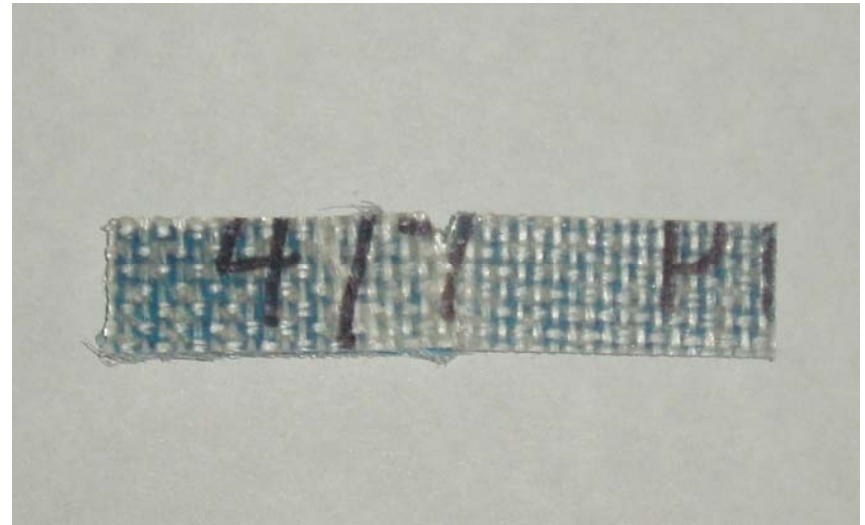
Flexural Strength



Izod Impact Results

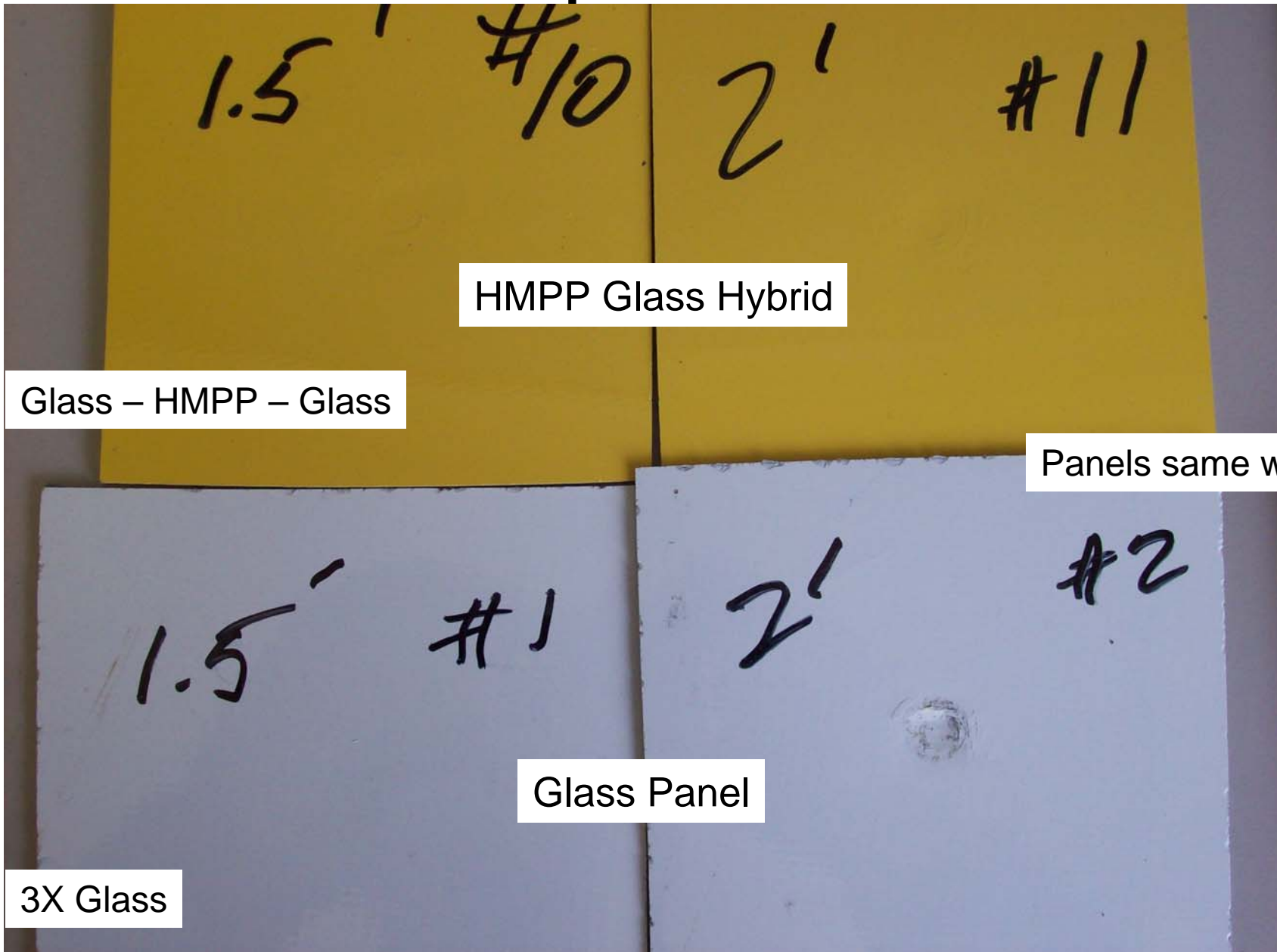


- Glass
 - Clean break
 - 19.7 ft-lbs/inch



- 4/4 Glass – HMPP
 - Hinged break—HMPP did not break
 - 20.5 ft-lbs/inch

Dart Impact Results



HMPP Glass Hybrid

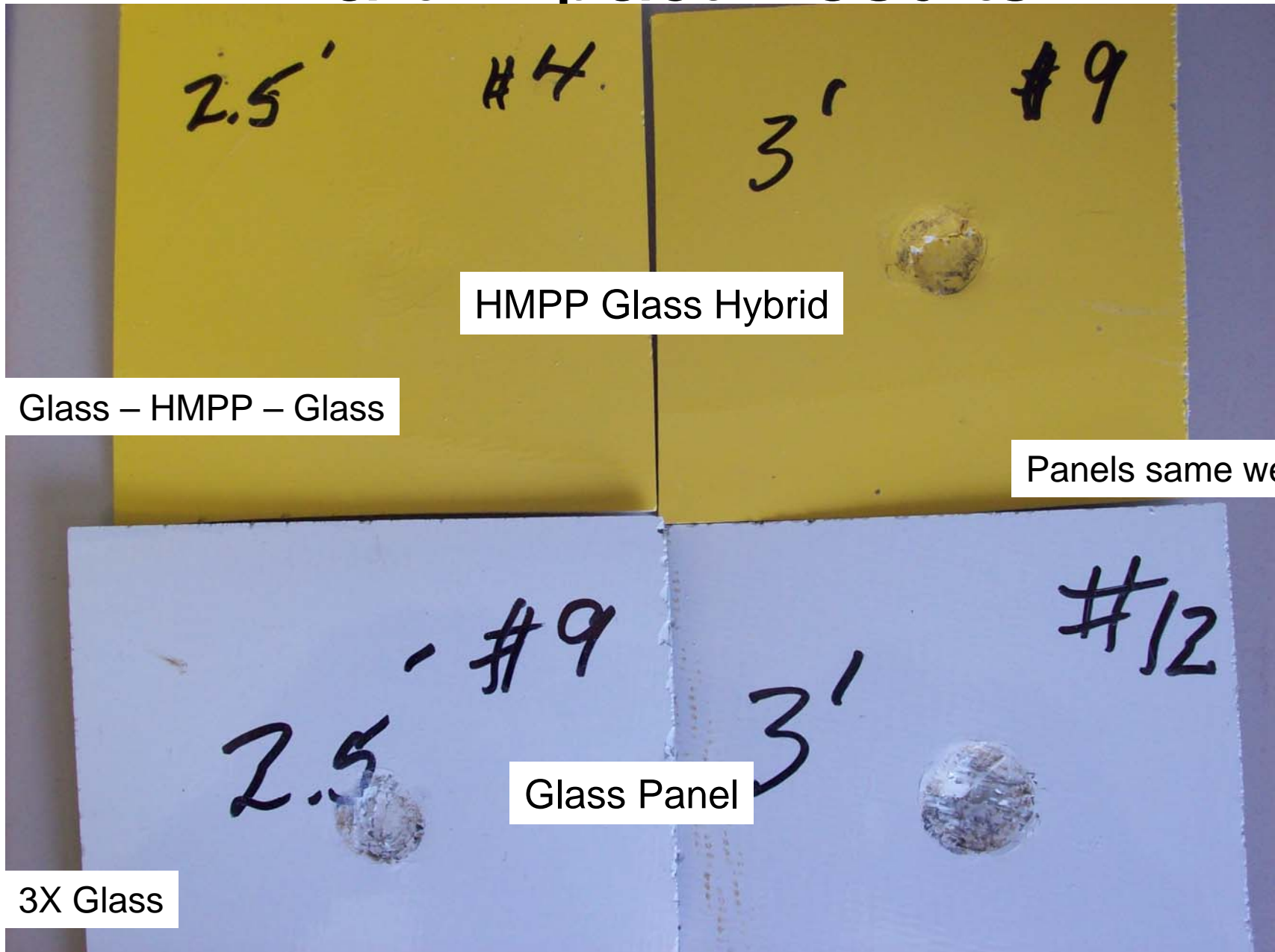
Glass – HMPP – Glass

Panels same weight

Glass Panel

3X Glass

Dart Impact Results



2.5' #4

3' #9

HMPP Glass Hybrid

Glass – HMPP – Glass

Panels same weight

2.5' - #9

3' #12

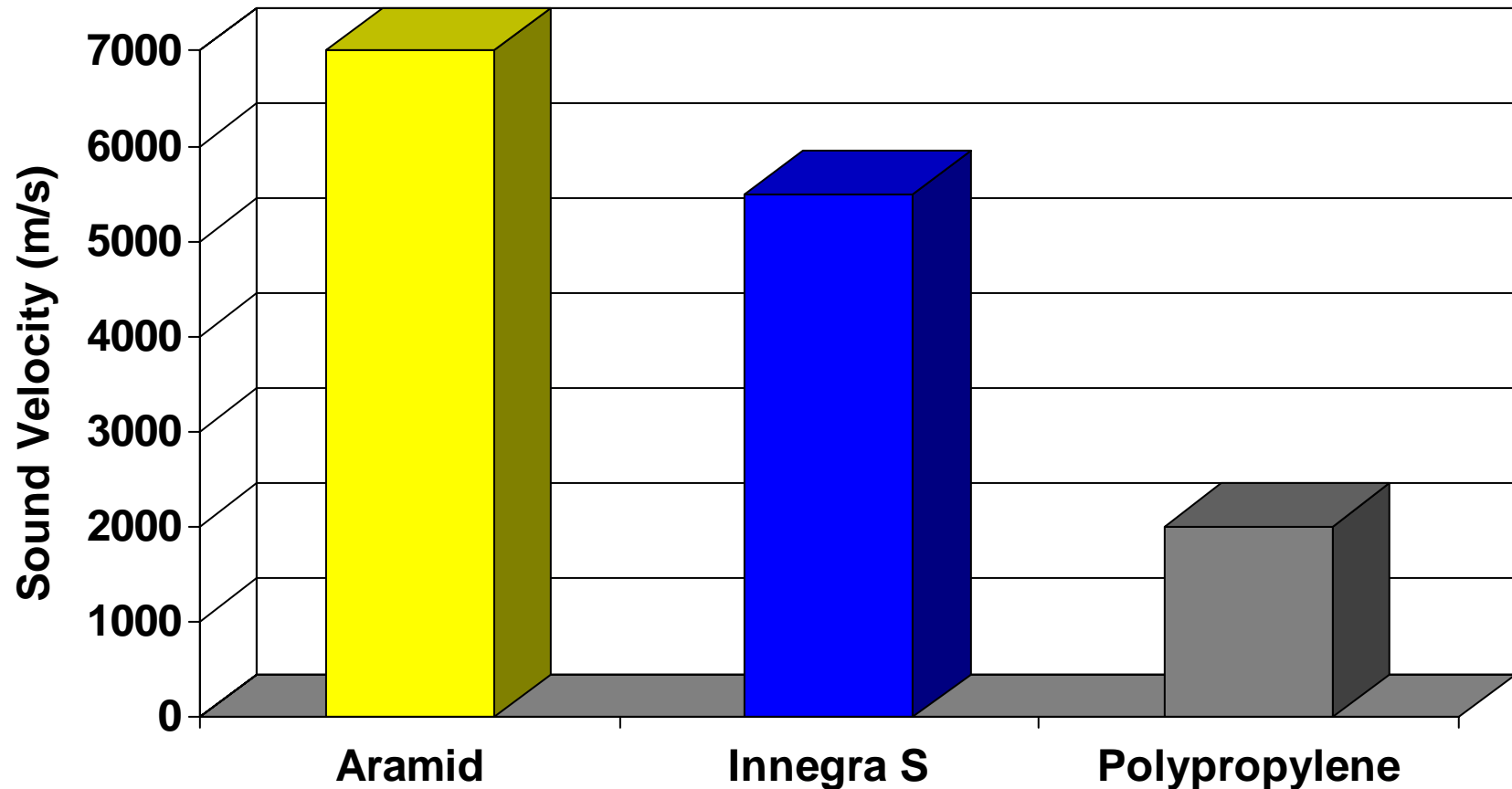
Glass Panel

3X Glass

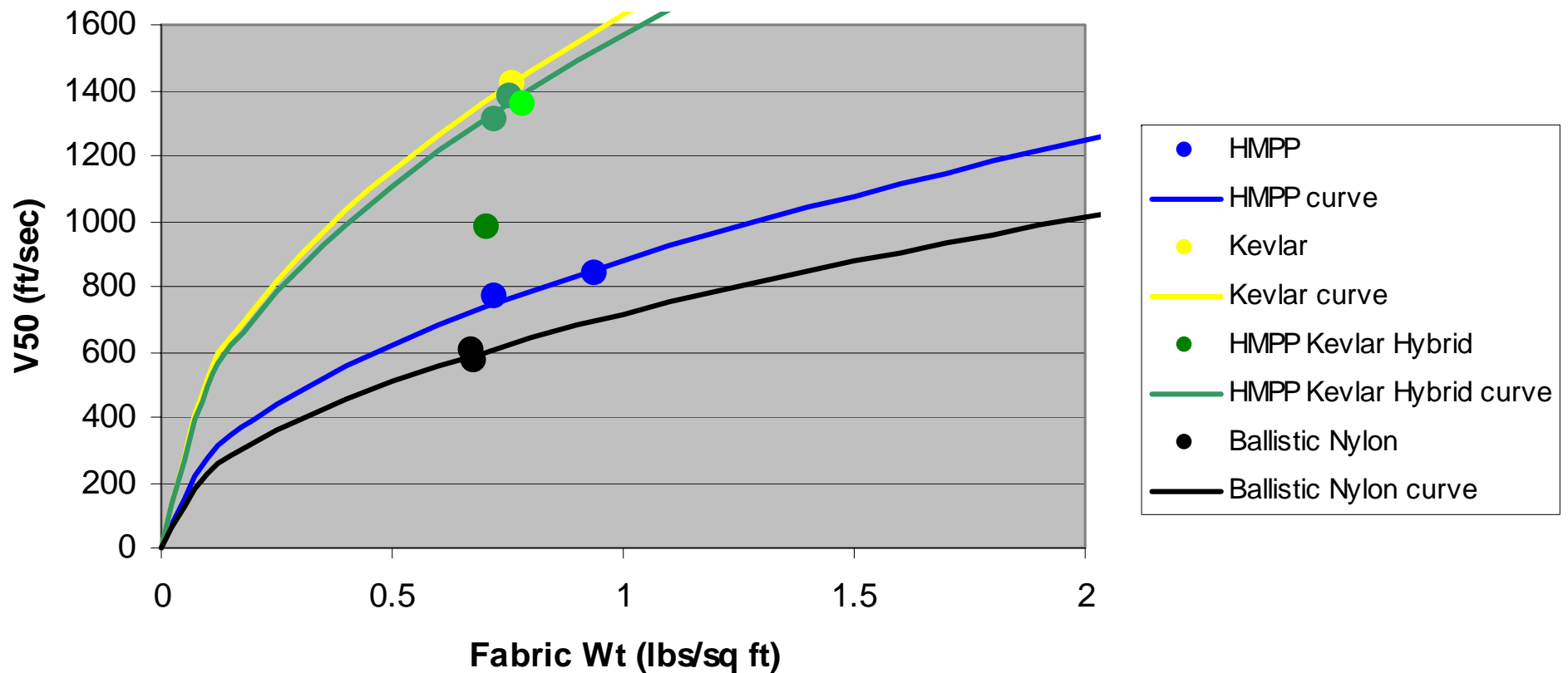


HMPP – Aramid Hybrids

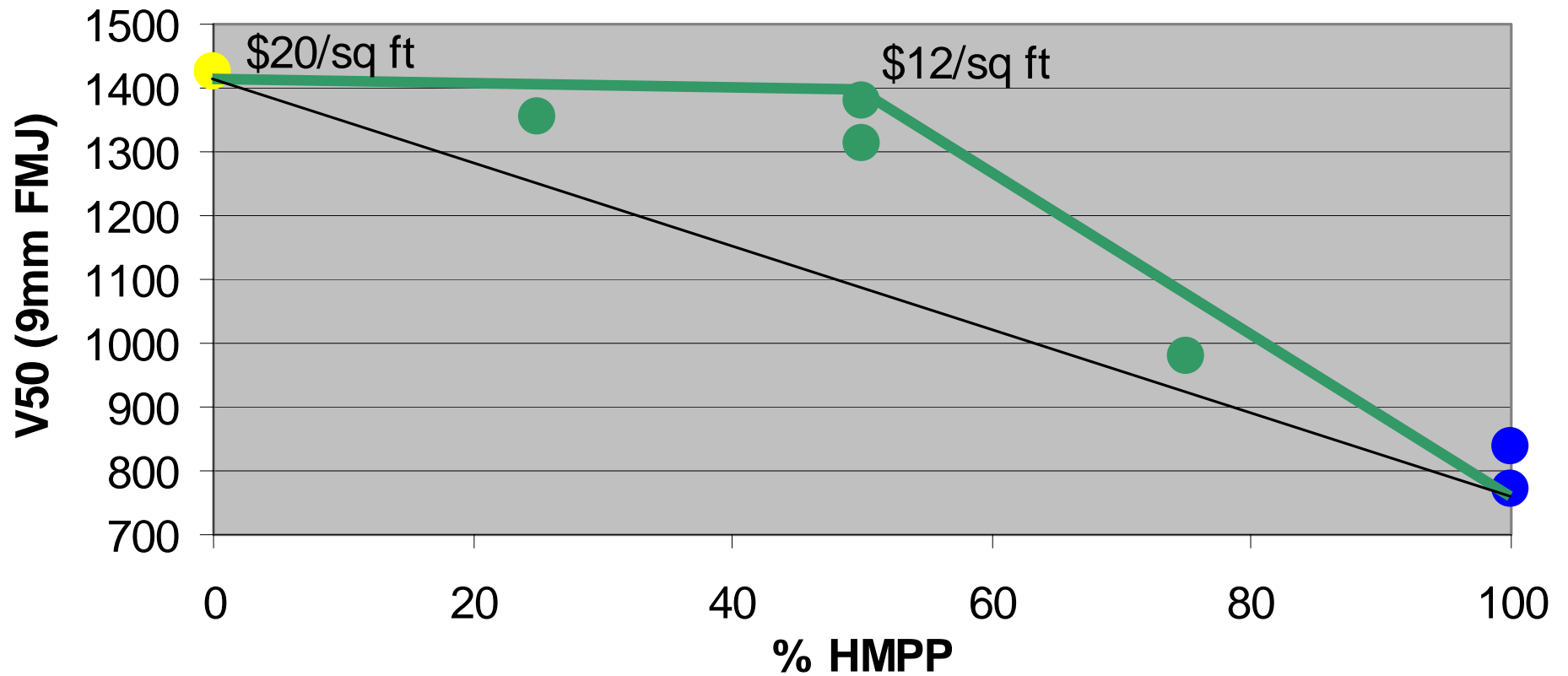
Fiber Sound Velocity (m/s)



9mm V50 vs Fabric Wt



HMPP Ballistics



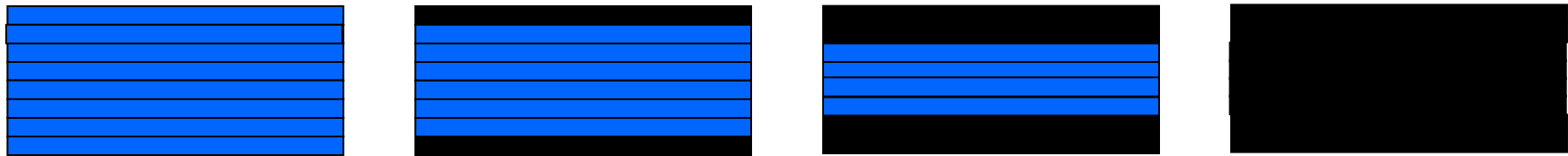
Hard Ballistic Panel

- HMPP
 - 2800 d 15 x 14 plain weave, 12.5 oz/sq yd
 - 15 ply, polyolefin film 15%
 - 1.5 lbs/sq ft, 0.42” thick
 - 0.44 cal, 1258 ft/sec
 - Less costly than all S-glass at similar performance



HMPP – Carbon Hybrids

Composite Samples



A

B

C

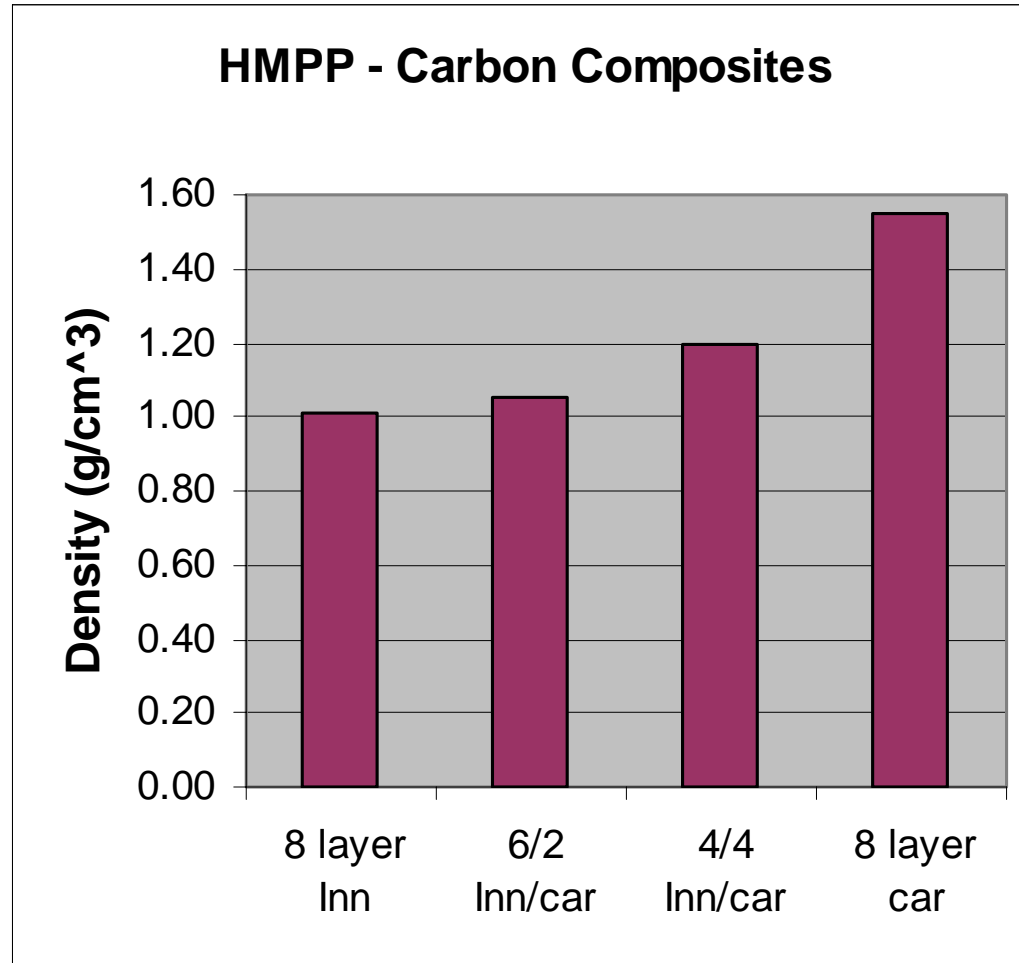
D

■ HMPP

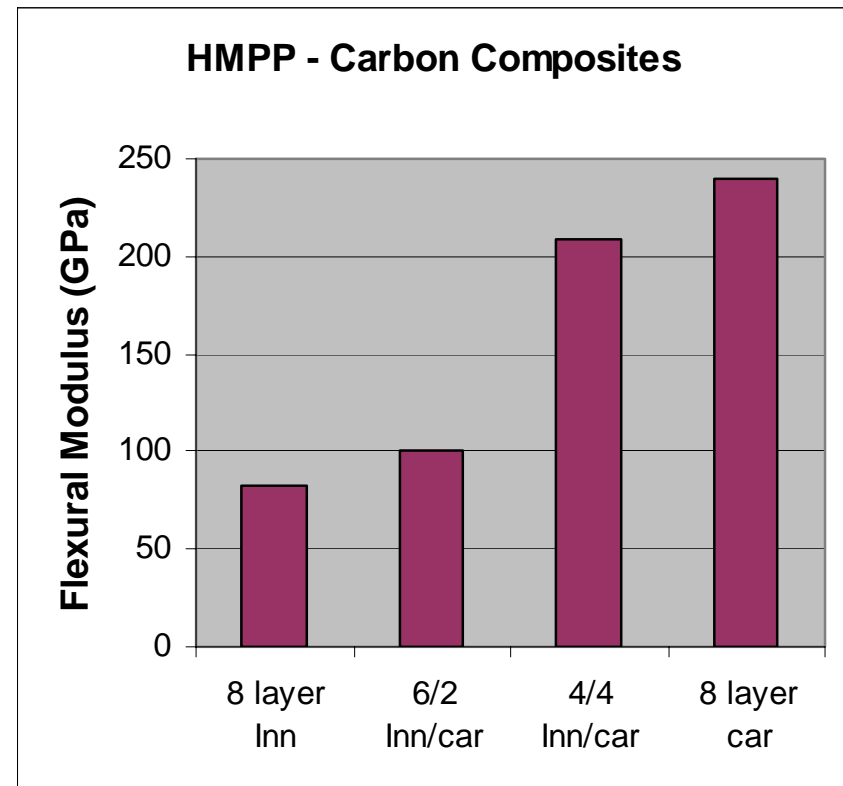
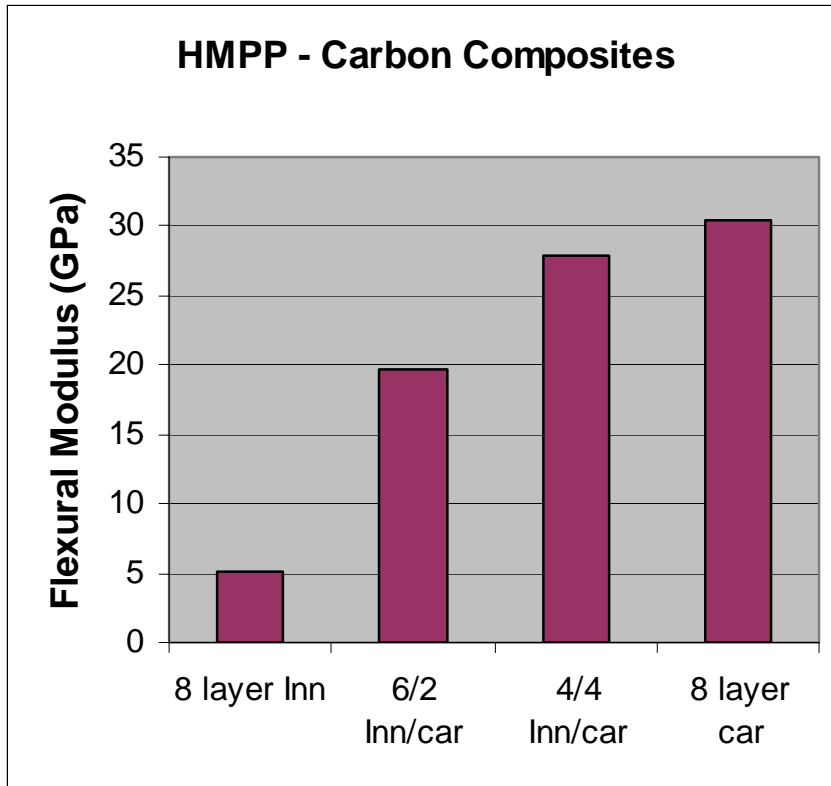
■ Carbon

- 8 Layer composites
- Epoxy resin
- Two-sided mold (6" x 2", open ends)
- 24 hr RT cure

Carbon: Density & Dielectric



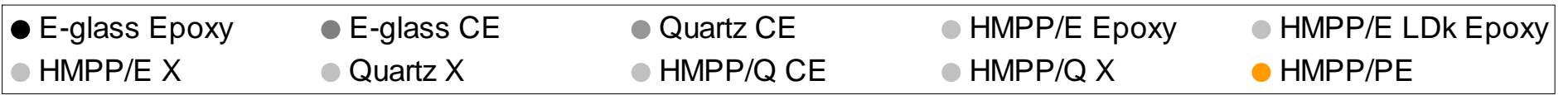
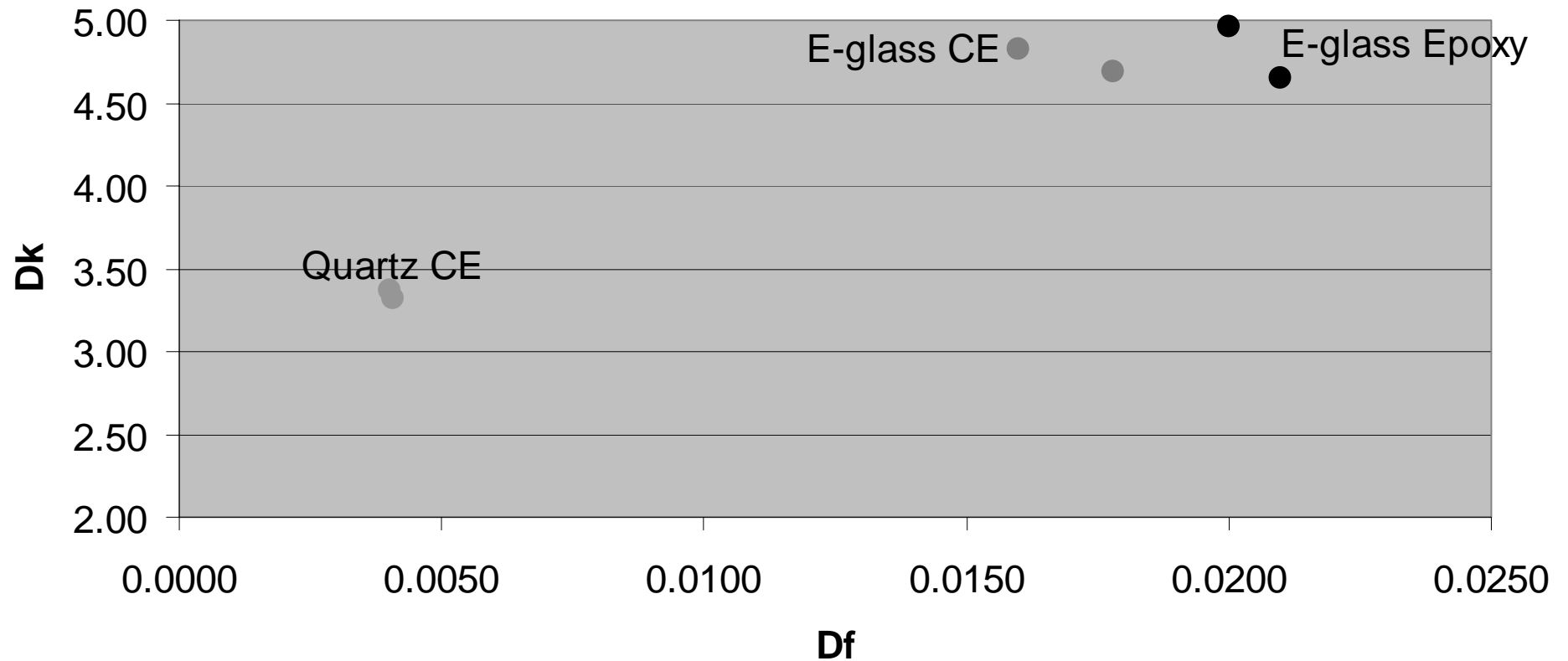
Carbon: Flexural Strength & Modulus



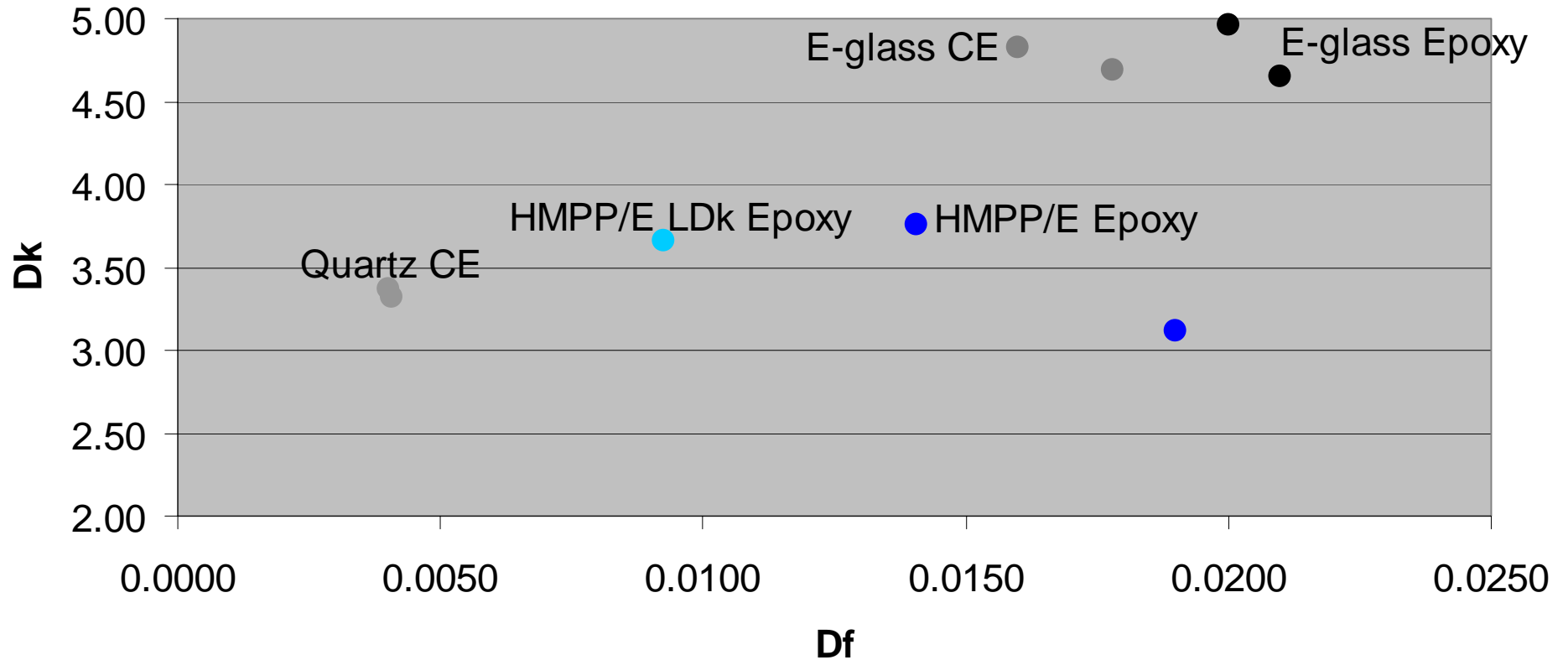


HMPP – Quartz Hybrids

Existing Radome Materials

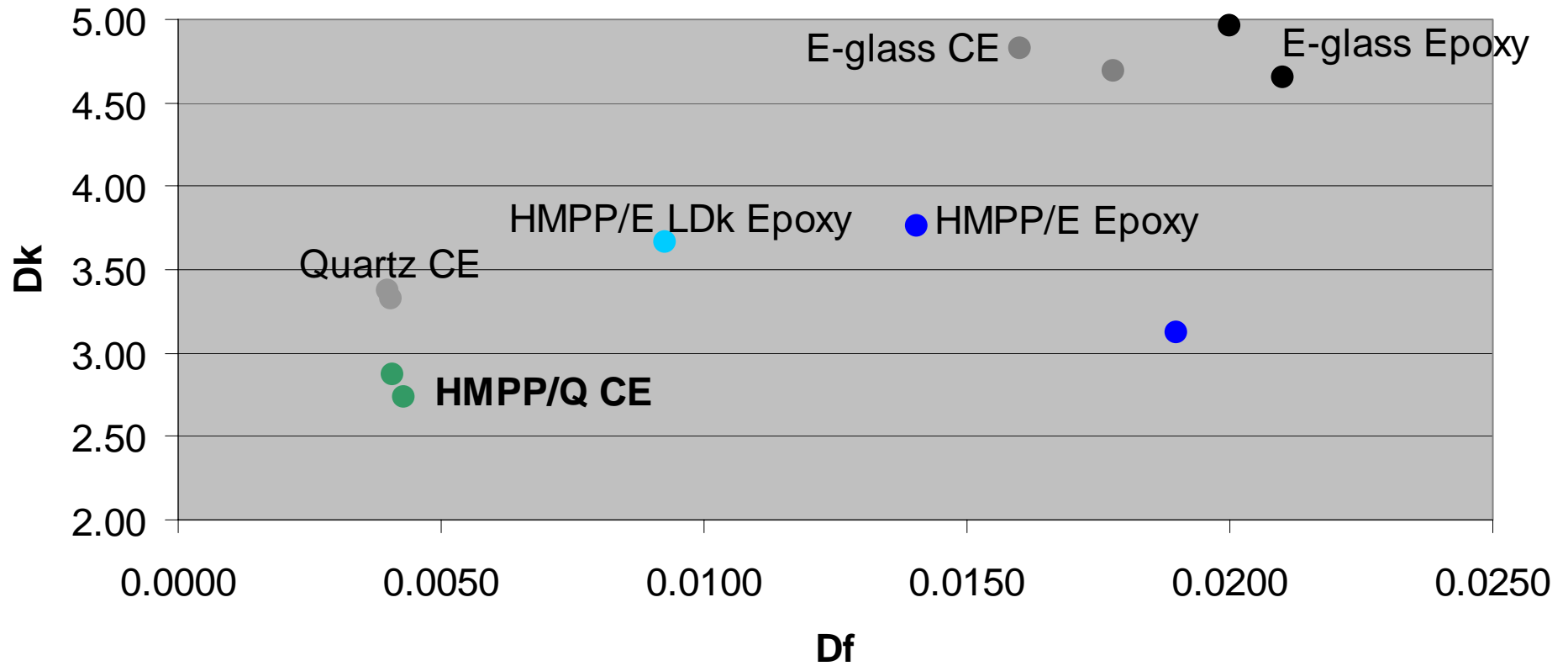


HMPP/E-glass Epoxy



- | | | | | |
|-----------------|--------------|-------------|----------------|--------------------|
| ● E-glass Epoxy | ● E-glass CE | ● Quartz CE | ● HMPP/E Epoxy | ● HMPP/E LDk Epoxy |
| ● HMPP/E X | ● Quartz X | ● HMPP/Q CE | ● HMPP/Q X | ● HMPP/PE |

HMPP/Quartz CE

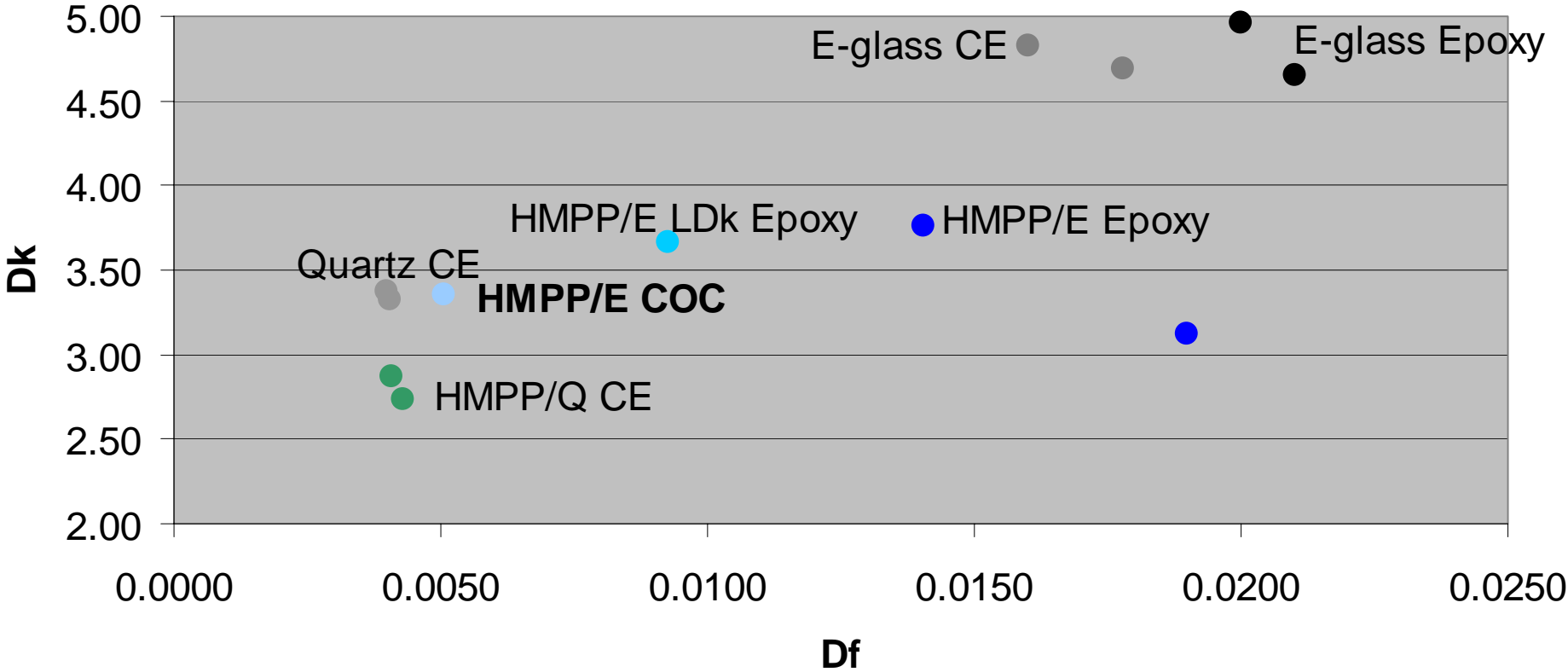


- | | | | | |
|-----------------|--------------|-------------|----------------|--------------------|
| ● E-glass Epoxy | ● E-glass CE | ● Quartz CE | ● HMPP/E Epoxy | ● HMPP/E LDk Epoxy |
| ● HMPP/E X | ● Quartz X | ● HMPP/Q CE | ● HMPP/Q X | ● HMPP/PE |

COC Resin Properties

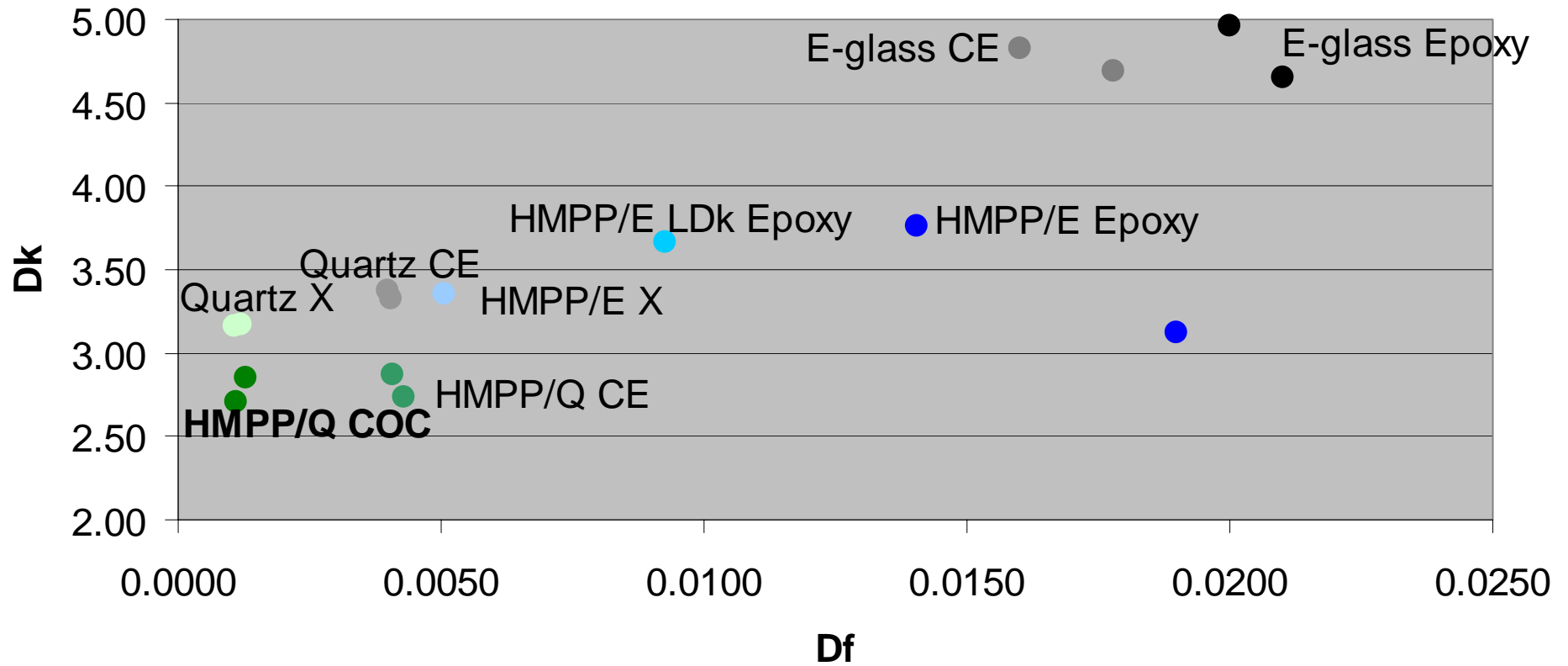
Property	COC	Cyanate Ester
Dielectric Constant	2.35	2.76
Dielectric Loss	0.0002	0.006
Density	1.02	1.21
Tensile Modulus	3000	3300
Tensile strength	58	60
Water absorption	<0.01%	

HMPP/E-glass



- E-glass Epoxy
- E-glass CE
- Quartz CE
- HMPP/E Epoxy
- HMPP/E LDk Epoxy
- HMPP/E X
- Quartz X
- HMPP/Q CE
- HMPP/Q X
- HMPP/PE

HMPP/Quartz COC



- E-glass Epoxy
- E-glass CE
- Quartz CE
- HMPP/E Epoxy
- HMPP/E LDk Epoxy
- HMPP/E X
- Quartz X
- HMPP/Q CE
- HMPP/Q X
- HMPP/PE

HMPP/Quartz/X Physicals

Sample	Fiber/ Resin	Density	Flex Modulus	Flex Strength
4581	Quartz/ CE	1.79	28	716
4581	Quartz/ X	1.74	18.4	320
15361	Quartz/ HMPP/ X	1.38	22.3	362
15406	Quartz/COC/ X	1.59	19.9	301

Summary

- HMPP
 - Light weight
 - Tough
 - Low dielectrics
- Applications
 - Marine
 - Radome
 - Ballistics



Brian Morin, Ph.D.

Brian Follo

Jennifer Medlock

(Suzanne Hofford)

Innegrity LLC
59-C Concourse Way
Greer, SC 29650

(864) 248-6077

Brian.Morin@Innegrity.com

Brian.Follo@Innegrity.com

Jennifer.Medlock@Innegrity.com

Suzanne.Hofford@Innegrity.com

www.Innegrity.com

INNegrITY Innovation with Integrity

INNegrITY™ Innovation with Integrity