Improving Adhesive Bonding of Composites Through Surface Characterization

(of Peel Ply Prepared Surfaces)

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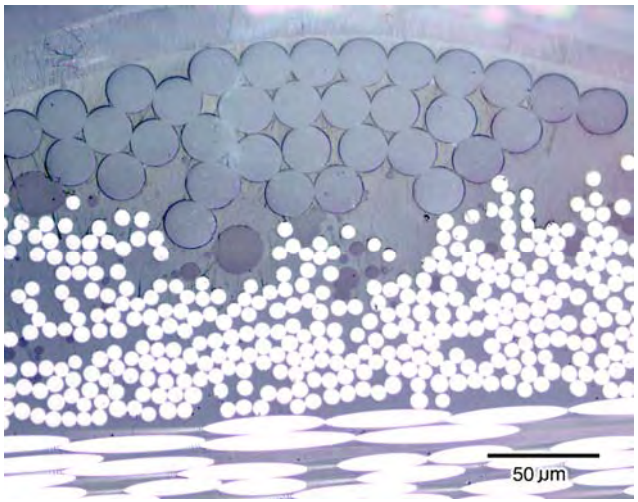
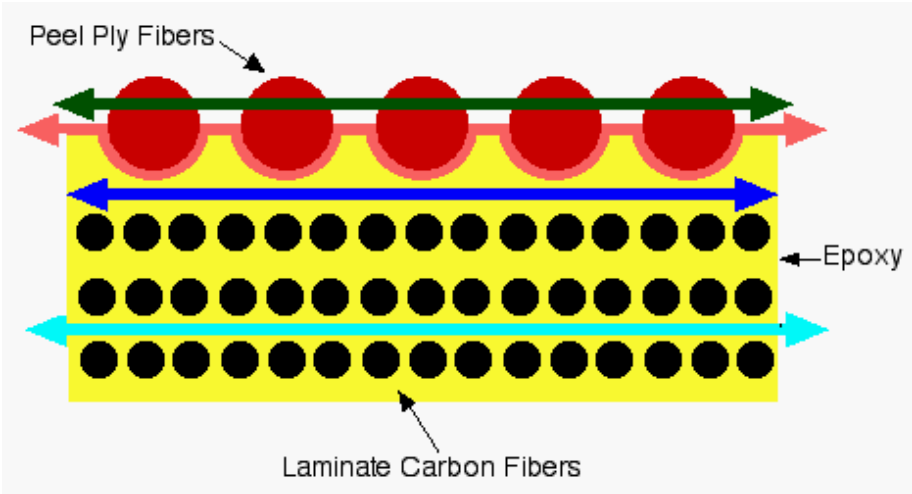
Improving Adhesive Bonding of Composites Through Surface Characterization

- Motivation and Key Issues
  - Peel ply surface preparation is being used for bonding primary structure
  - Good bonds are produced but questions remain:
    - What are appropriate techniques to inspect surfaces?
    - What are key factors for making a good/poor bond?
    - How to predict material and surface preparation compatibility?
- Objective
  - Further understand the effect of peel ply surface preparation on the durability of primary structural composite bonds through surface analysis coupled with mechanical testing and fractography

Peel Ply Surface Preparation



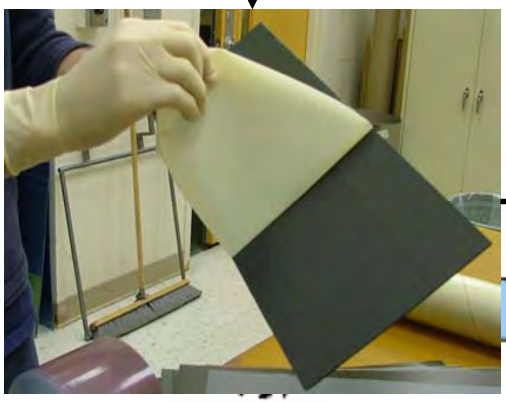
Fracture Possibilities Upon Peel Ply Removal



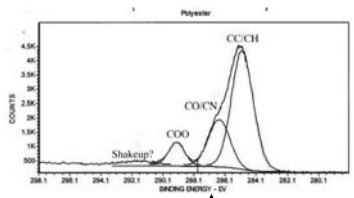
- Fracture of the epoxy between peel ply and carbon fibers
  - Fresh, chemically active, epoxy surface is created
- Interfacial fracture between the peel ply fabric fibers and the epoxy matrix
- Peel ply fiber fracture
- Interlaminar failure

Samples were produced with standard composite processes and characterized

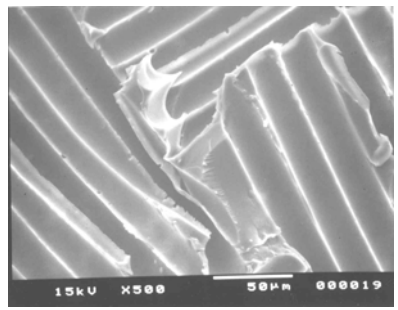
Autoclave Cure



Peel ply removed before bonding



Characterization Via XPS,SEM,Contact Angle



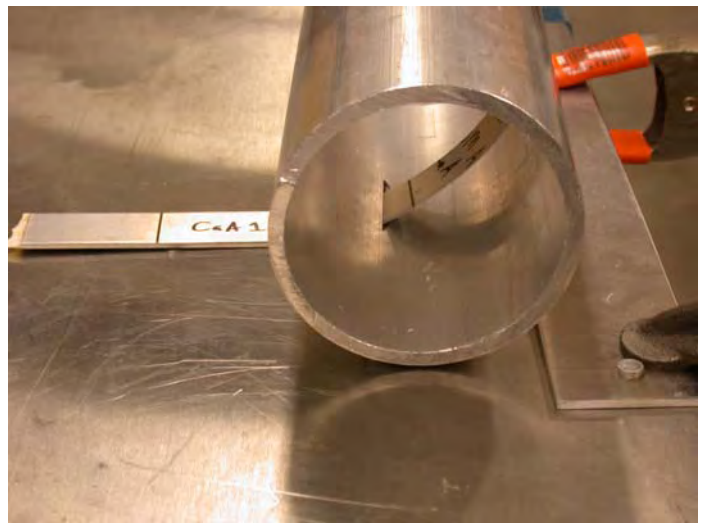
Bonded with film adhesive

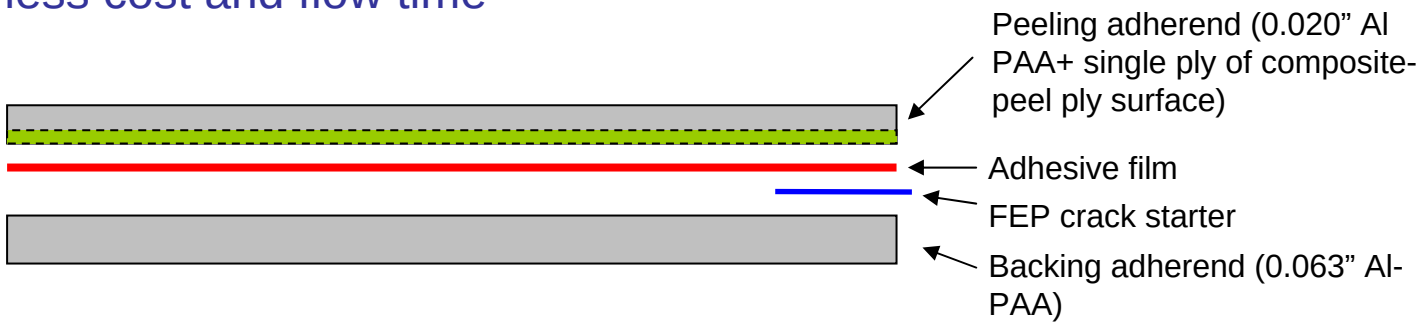
Autoclave Cure

Mode I testing

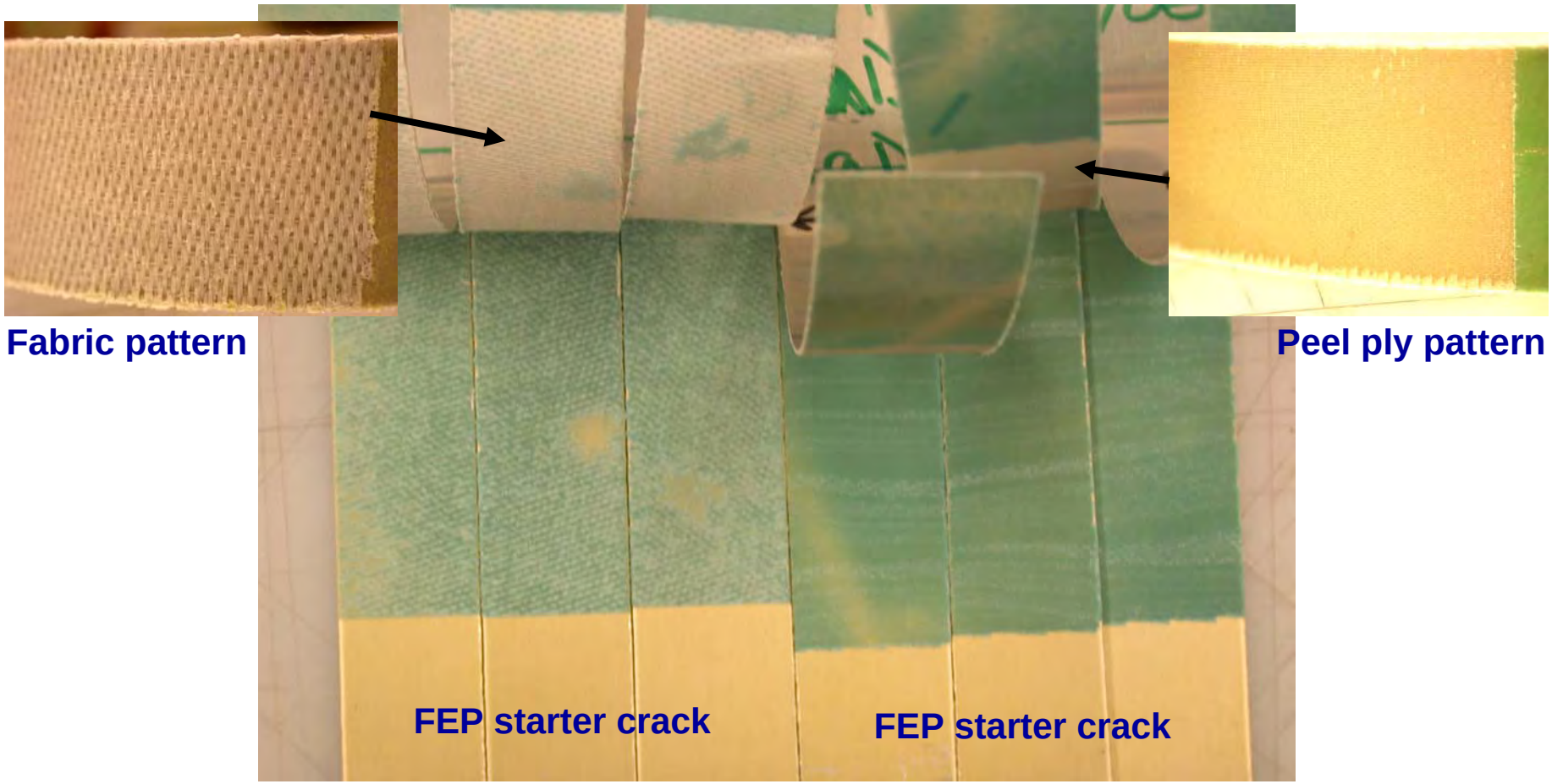
The Rapid Adhesion Test (RAT) Method

- A quick, low cost test which assesses the adhesion between metal-composite bonds.
- A modification of metal-to-metal peel test developed by Boeing.
- The backing adherend clamped to while the peeling adherend is removed
- Failure mode representative of bond
  - Adhesion Failure-Poor Bond
  - Cohesive Failure-Strong Bond
- Failure modes correlate with DCB test with ~90% less cost and flow time





RAT Method Assessment



Cohesive failure (left) vs. Adhesion failure (right)

Peel Ply Material-250F Cure GFRP

SUMMARY

Nylon - Strong

Polyester - Weak

RAT results						
updated:	3/24/2006		key:		strong bond	
spec:	BMS 8-79				mixed strong / very strong bonds	
					mixed results	
					weak bond	
Prepreg:	HexPly F155				other	
	adhesive:					
peel ply:	3M AF500	3M AF163-2	Cytec FM94	Henkel EA 9696	Cytec FMx 209	Henkel EA 9628
60001 (polyester)						
51789 (nylon)						
Prepreg:	Yokohama G7781					
	adhesive:					
peel ply:	3M AF500	3M AF163-2	Cytec FM94	Henkel EA 9696	Cytec FMx 209	Henkel EA 9628
60001 (polyester)						
51789 (nylon)						
Prepreg:	Cytec MXB7701					
	adhesive:					
peel ply:	3M AF500	3M AF163-2	Cytec FM94	Henkel EA 9696	Cytec FMx 209	Henkel EA 9628
60001 (polyester)						
51789 (nylon)						

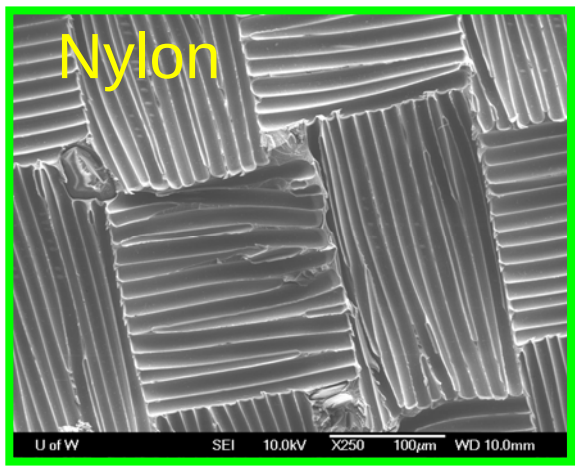
Peel Ply Material-350F Cure CFRP

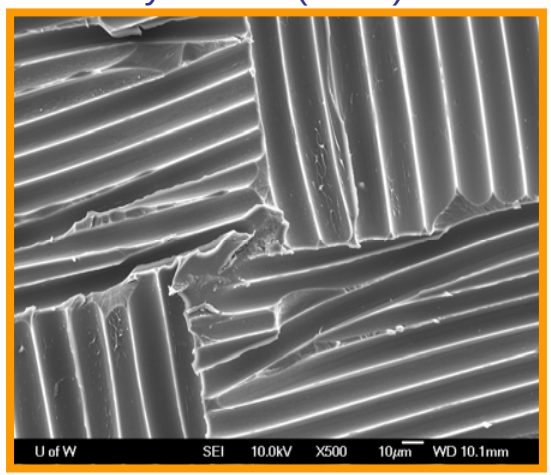
	PEEL PLY USED FOR SURFACE TREATMENT				
Substrate Adhesive	PF60001 Polyester	PF51789 Nylon	Fiberglass-Epoxy	EA9895 PE-Epoxy	Nylon-Epoxy
Cytec 970 MB1515-3	MIXED	ADHESION	COHESIVE	COHESIVE	ADHESION
Cytec 970 AF555	MIXED	MIXED	COHESIVE	COHESIVE	COHESIVE
Toray 3631 MB1515-3	ADHESION	ADHESION	NA	COHESIVE	ADHESION
Toray 3631 AF555	ADHESION	ADHESION	NA	COHESIVE	ADHESION
Toray 3900 MB1515-3	COHESIVE	ADHESION	NA	NA	NA
Toray 3900 AF555	COHESIVE	COHESIVE	NA	NA	NA

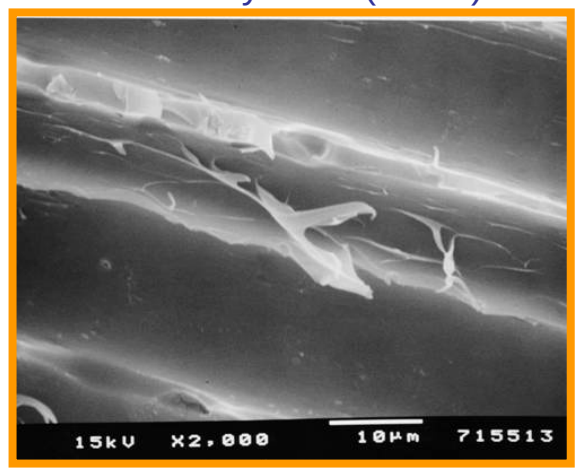
Peel Ply Surface Prep. - SEM Results

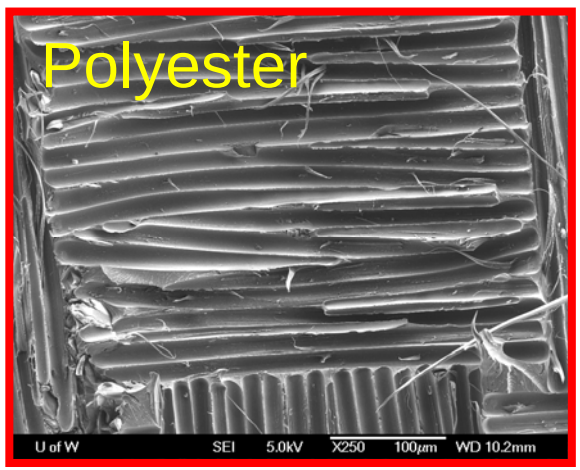
Composite surface after removal of:

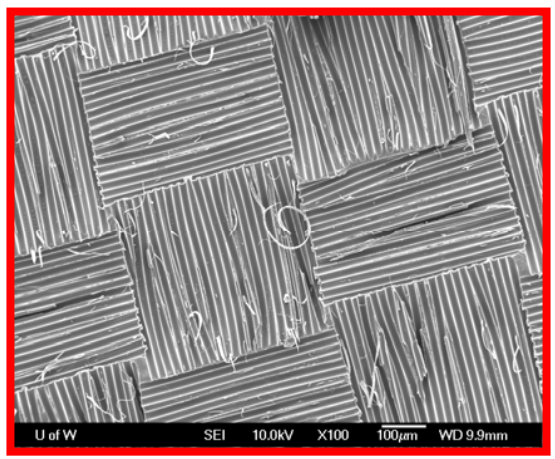
260 F cure GFRP	Cytec 970 (360F)	Toray 3900 (360 F)
Nylon		
Polyester		

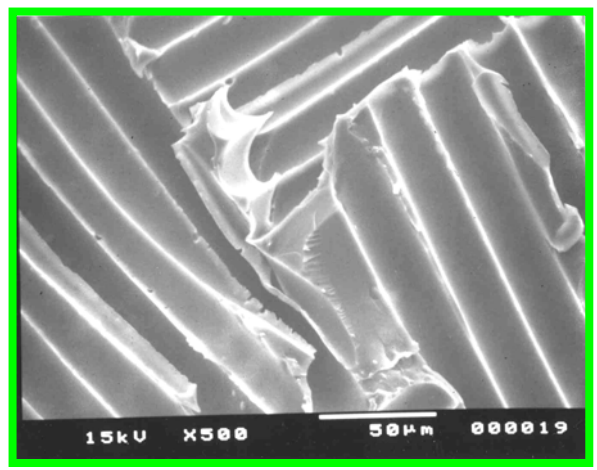






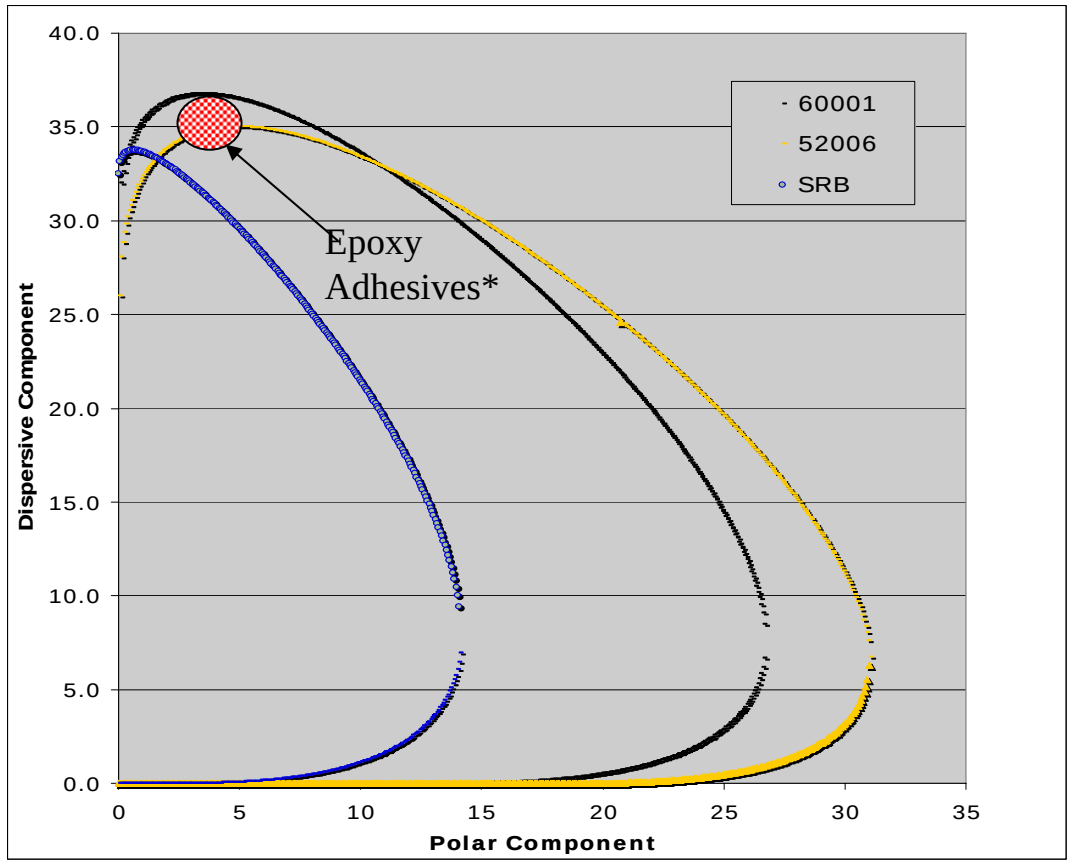






Wettability envelopes showed the difference in the prepared surfaces.

- Fluids inside the envelope will wet spontaneously
  - Critical condition for bonding?
- Wettability envelopes a potential method to determine suitability of a surface for bonding
- Epoxy adhesives* on boundary for nylon prepared surfaces

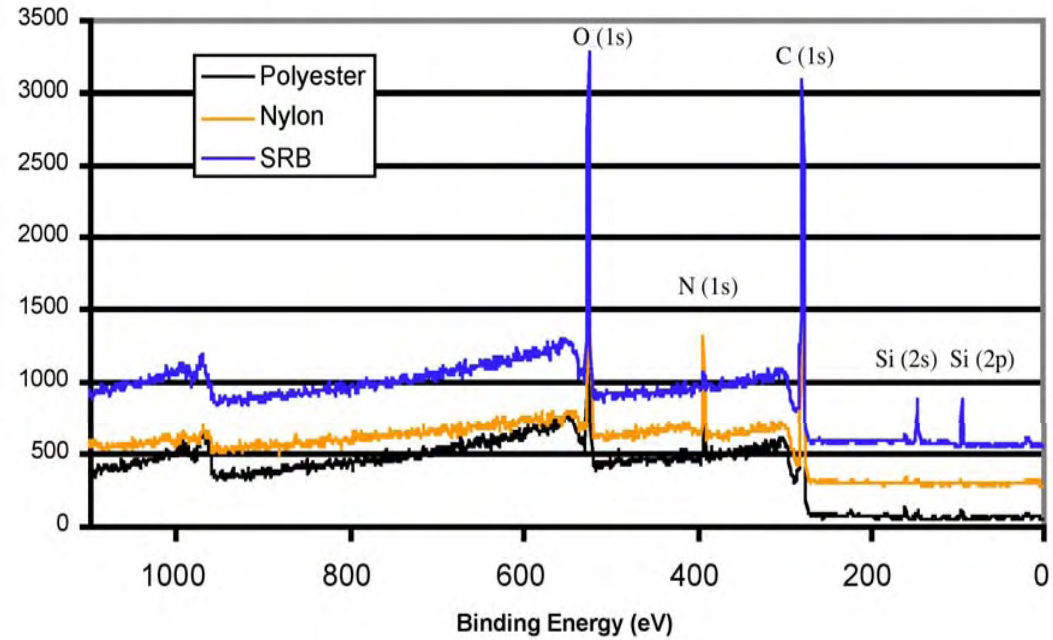


*** Literature values for aerospace epoxies**

- Curves generated using WET program (M. Tuttle)

XPS Survey Scan Results

Laminate surfaces before bonding, after peel ply removal



Laminate Surface Composition

Peel Ply	%C	%O	%N	%Si
Nylon	77.5	12.6	9.8	Tr.
Polyester	75.5	21.6	1.9	Tr.
SRB	68	24.2	0.9	6.9

- Si explains SRB low bond quality….Siloxane coating transfers
- Amount of N on nylon peel ply prepared sample surprising

Conclusions

- Bonding Depends on
  - Prepreg system (Resin and Fiber(?))
  - Peel Ply Material and Source
  - Adhesive
- Characterization Techniques (XPS, SEM and Surface Energy) provide useful information to help understand bonding requirements

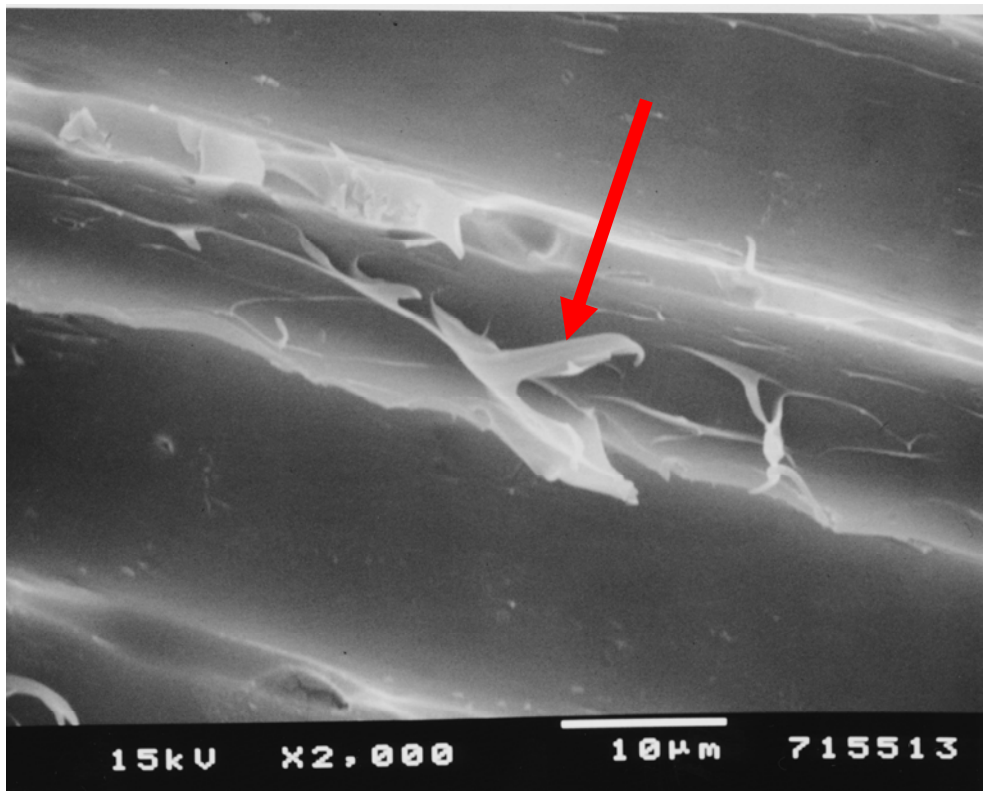
A Look Forward

- Benefit to Aviation
  - Better understanding of peel ply surface prep.
  - Guide development of QA methods for surface prep.
  - Greater confidence in adhesive bonds

- Future needs
  - Contact angle (wetting) vs. bond quality
  - Does fiber type (glass, pitch, PAN) effect bonding?
  - Peel ply-resin interactions
  - Applicability to other composite and adhesive systems
  - Model to guide bonding based on characterization, surface prep. and material properties

A Closer Look at the Laminate Surface

Laminate surface after removal of nylon peel ply



Nylon from peel ply on surface before bonding?

350F CURE SYSTEM SUMMARY

Bond Quality Depends on:

- Peel Ply Material and Adhesive
  - Polyester peel ply: high toughness bonds, cohesive failure both adhesives
  - Nylon: low toughness, adhesion failure
  - One adhesive bonded well to all surfaces
- H_20 Contact angle did not correlate well with G_{IC}
- Wettability envelopes more accurate
- XPS can provide important chemical information

250F Cure Systems

- 2 Peel Plies: Polyester 60001 and Nylon 52006
- 3 prepregs-260 ºF cure
  - HexPly® F155
  - Yokohama G7781
  - Cytec MXB7701
- 6 adhesives-260 ºF cure
  - 3M AF500; 3M AF163-2;
  - Henkel EA 9696; Henkel EA 9628
  - Cytec FM94; Cytec FMx 209
- Bond quality assessed by failure mode
  - Adhesion (poor) vs. Cohesive (good)

250F CURE SYSTEM SUMMARY

Bond Quality Depends on:

- Peel Ply Material and Adhesive
  - Nylon : high toughness bonds, cohesive failure all adhesives
  - Polyester peel ply: low toughness, adhesion failure
  - One adhesive bonded well to all surfaces
- Opposite Trend than 350 F system
  - Nylon bad, Polyester good