

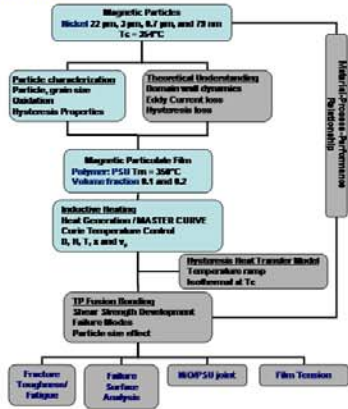
HYSTERESIS BONDING OF THERMOPLASTIC COMPOSITE USING NICKEL/POLYSULFONE ADHESIVE FILMS

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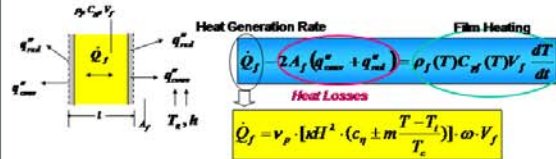
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RESEARCH OVERVIEW

The goal of this research is to establish the science base for design of magnetic particle/polymer systems for hysteresis heating with potential application in novel polymer composite processing and repair techniques.



HYSTERESIS HEAT GENERATION MASTER CURVES



Key parameters for Ni/PSU:

Oxidation ratio (x), $\frac{D_1^3}{D_2^3} = 1 - x$

Particle volume (v_p), $v_p^* = \frac{v_p \cdot (1 - x)}{1 + v_p \cdot x \cdot (z - 1)}$; $z = 1.53$ for Ni/NiO

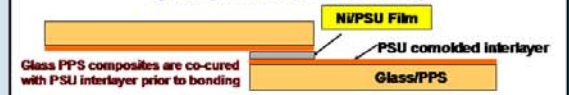
Applied field (H), $\dot{Q}_p(H) = kH^4$

Particle sizes (D), $\kappa = 2.05 \times 10^{-4} + \frac{6.85 \times 10^{-7}}{D_1} \lambda = 0.17 \log(\frac{D_1}{D_2}) + 3.60$; $D_1 = 1 \mu m$

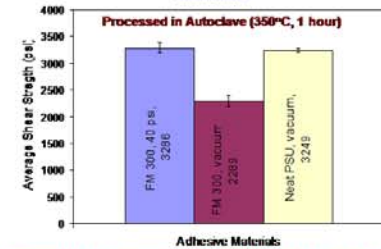
Temperature (T) $T_c < T < T^*$; $c_p = 1.0$; $m_s = 2.05 - 0.3 \log D_1$
 $T^* < T < T_c$; $c_p = 30$; $m = -59.2$

THERMOPLASTIC COMPOSITE FUSION BONDING

Schematic of Thermoplastic Composite Fusion Bonding System [PPS/PSU/Ni-PSU/PSU/PPS]

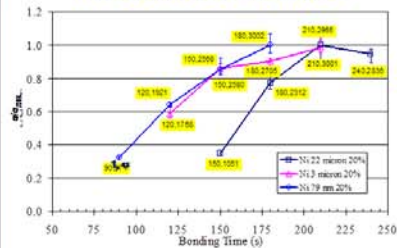


The standard lap joint of Glass/ PPS with various adhesive materials



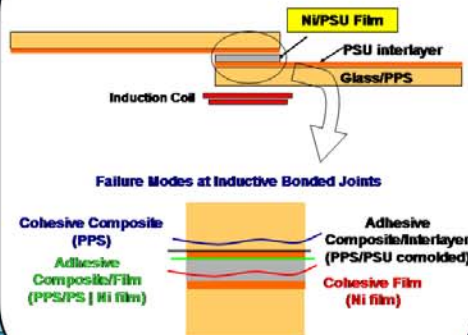
Thermoplastic adhesive (PSU) provides shear strength that is comparable to the commercial aerospace adhesive (FM300)

INDUCTION BONDING USING Ni/PSU ADHESIVE FILMS

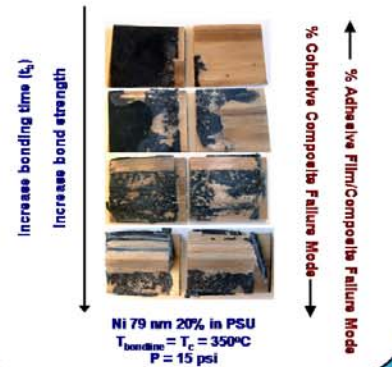


Ni/PSU for induction bonding provides comparable shear strength at much shorter time.
 Degree of induction bonding depends on thermal history in the bondline and pressure (constant in this study).

INTERFACES AND FAILURE MODES



FAILURE MODES vs. BONDING TIME

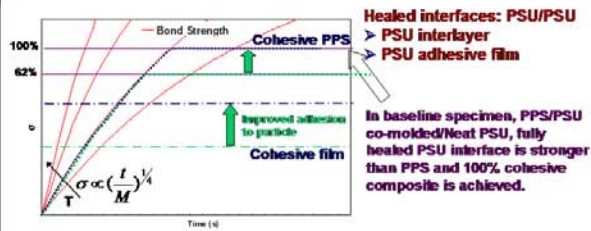


FAILURE MODES

t_b	Failure Modes			
	Adhesive Film (PPS/PSU/Ni Film)	Cohesive Film (Ni Film)	Cohesive Composite (PPS)	Adhesive PPS/ Interlayer Co-molded (PPS/PSU)
0 s	0%	0%	0%	0%
90 s	75%	25%	0%	0%
120 s	45%	55%	0%	0%
150 s	1%	73%	22%	0%
180 s	0%	38%	62%	0%
-	0%	0%	100%	0%

An ideal case of 100% cohesive composite indicates failure mode in PPS/PSU comolded/ neat PSU bonding.

BOND STRENGTH DEVELOPMENT



In hysteresis bonding specimens, cohesive Ni film failure is dominant. Maximum bond strength (fully healed) specimen failed with 62% cohesive composite and 38% cohesive film failure. (-----)

To raise the level of bond strength such that specimen fail at 100% cohesive composite, the adhesion of nickel particle in PSU should be improved. (- - - - -)

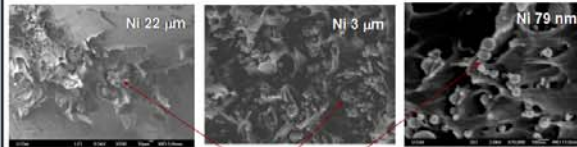
The failure modes between Ni and PSU in adhesive film should be investigated.

FRACTURE SURFACES ANALYSIS

- Type of Fracture Surfaces in Ni/PSU Adhesive Film
 - Cohesive PSU Matrix
 - Adhesive Particle/Matrix



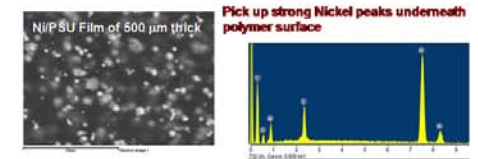
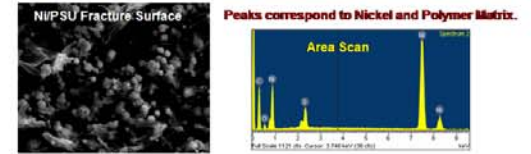
SEM micrograph of the cohesive film failure surfaces



Nickel Particles

- The microstructure of cohesive film failure surfaces show what seem to be "Adhesive Particle/Matrix Failure"
- In order to confirm the observation of failure mode in the Ni/PSU adhesive films, XEDS spectrum are obtained.

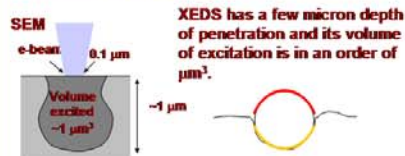
X-RAY ENERGY DISPERSIVE SCATTERING ANALYSIS



What are the Failure Modes at Particle/Matrix Interface?

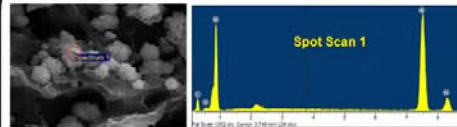
SPATIAL RESOLUTION

- Spatial resolution governed by the beam-specimen interaction volume (a function of beam diameter and beam spreading), since the XEDS can detect X-rays generated anywhere within that volume.
- An improvement in spatial resolution is balanced by a worsening of the detectability limit.



Trace of polymeric material can be detected from the top of particle or from the bottom of particle.

ADHESIVE OR COHESIVE



Particle size ~ 2-3 μm Spot scan reveals trace of polymeric matrix and nickel particles

Adhesive Particle/Matrix or Cohesive Matrix/Matrix or Resolution Limitation?

- The failure mode in adhesive film cannot be conclusively identified from the XEDS results.
- A better surface analysis technique such as XPS is a good candidate as the technique has spatial resolution in an order of nanometer.

CONCLUSIONS

- Hysteresis welding offers bond strength that is comparable to the level of strength achieved from the autoclave bonding method with an order of magnitude reduction in cycle times.
- The failure modes change from adhesive film/composite to cohesive composite/composite and cohesive Ni film as dwell time increases and maximum bond strength is achieved.
- The failure mode in film characterized from XEDS is ambiguous and further characterization using XPS are needed.

FUTURE WORK

- Fracture toughness
 - Influence of particles on plastic zone size in films and in composite joints (such as DCB)
- NiO/PSU lap joint that can be examined by SEM, XEDS, XPS
 - Parameters: Particle size, temperature, volume fraction and moisture
- Film Tension
 - Tension of PSU with loaded particle and neat PSU
 - Parameters: Particle size, temperature, volume fraction and moisture

ACKNOWLEDGEMENTS

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