Please see attached.
MEMORANDUM FOR PRS (In-House Publication) 22 May 2002

FROM: PROI (STINFO)

C.T. Liu (PRSM); F.P. Chiang (NYSU), "Investigating the Deformation and Failure Mechanisms in Bi-
Material Systems Under Tension"

ASME Winter Meeting
(Blacksburg, VA, 24-28 June 2002) (Deadline = 23 June 2002)

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Investigating the Deformation and Failure Mechanisms in Bi-Material Systems under Tension

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Objectives

¥ Investigate the Local Strain Distribution and Failure Mode in a Bi-Material Bonded Specimens under a Constant Displacement Rate Condition.

  * Displacement Rate = 0.02 in/min

¥ Determine the Critical Strain for Debond at the Interface between the Two Materials.
Experimental Set-Up

Light source → CCD

Specimen → Viewed area

F

x

y

Video camera
The Mechanism of Debonding

Thickness to Width Ratio: 1:1:00
The Mechanism of Debonding

Thickness to Width Ratio: 1:2.25
The Mechanism of Debonding

Thickness to Width Ratio: 1:5.00
The Debonding Modes

<table>
<thead>
<tr>
<th>Size: t x w (in)</th>
<th>Ratio: t:w</th>
<th>Number of Specimens</th>
<th>Debond at center</th>
<th>Debond at corner</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 x 1</td>
<td>1:5</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>0.2 x 0.5</td>
<td>1:2.5</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>0.2 x 0.4</td>
<td>1:2</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>0.2 x 0.2</td>
<td>1:1</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

H ~ 4 in
h ~ 0.1 in

Critical ratio: ~ 1:2.25; either mode may prevail
Analysis of Deformation
Average Strain Versus Force Curves

Thickness to Width Ratio: 1:5.00

[Diagram showing strain vs. time with data points and trend lines]
Displacement Increment Distribution along y Direction

Five linear sections:

- AB: top part of composite
- BC: top interphase
- CD: pure liner
- DE: bottom interphase
- EF: bottom part of composite
Strain Rate versus Time Curves

Thickness to Width Ratio: 1:2.25

- ■ composite (top)
- ● interphase (top)
- ▲ liner
- ▼ interphase (bottom)
- ● composite (bottom)
Strain Rate versus Time Curves

Thickness to Width Ratio: 1:5.00

- composite (top)
- interphase (top)
- liner
- interphase (bottom)
- composite (bottom)

STRAIN RATE (1/min)

TIME (min)
The Time History of Local Strain near Interface

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.00599</td>
</tr>
<tr>
<td>4</td>
<td>0.03144</td>
</tr>
<tr>
<td>5</td>
<td>0.06837</td>
</tr>
<tr>
<td>6</td>
<td>0.12411</td>
</tr>
<tr>
<td>7</td>
<td>0.17151</td>
</tr>
<tr>
<td>8</td>
<td>0.26691</td>
</tr>
</tbody>
</table>

Crack initiation
## Summary of Debonding Initiation Strain

<table>
<thead>
<tr>
<th>Specimen #</th>
<th>Size: t x w (in)</th>
<th>Ratio: t:w</th>
<th>Crack initiation strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>0.2 x 1</td>
<td>1:5</td>
<td>0.12</td>
</tr>
<tr>
<td>n</td>
<td>0.2 x 0.5</td>
<td>1:2.5</td>
<td>0.14</td>
</tr>
<tr>
<td>w</td>
<td>0.2 x 0.45</td>
<td>1:2.25</td>
<td>0.13</td>
</tr>
<tr>
<td>o</td>
<td>0.2 x 0.2</td>
<td>1:1</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Conclusions

¥ The Failure location depends on the geometry of the specimen.

¥ There are interphase regions near the interfaces of the specimen.

¥ The strain rates in the rubber layer and the interface region change with time.

¥ The strain rate in the interphase region is significantly higher than that in the rubber and the composite layers.

¥ The average critical local debond strain is 13%, which is independent of specimen geometry.