Controlling Moisture During Inner Layer Processing

John A. Marshall
MacDermid Inc.
Waterbury, CT

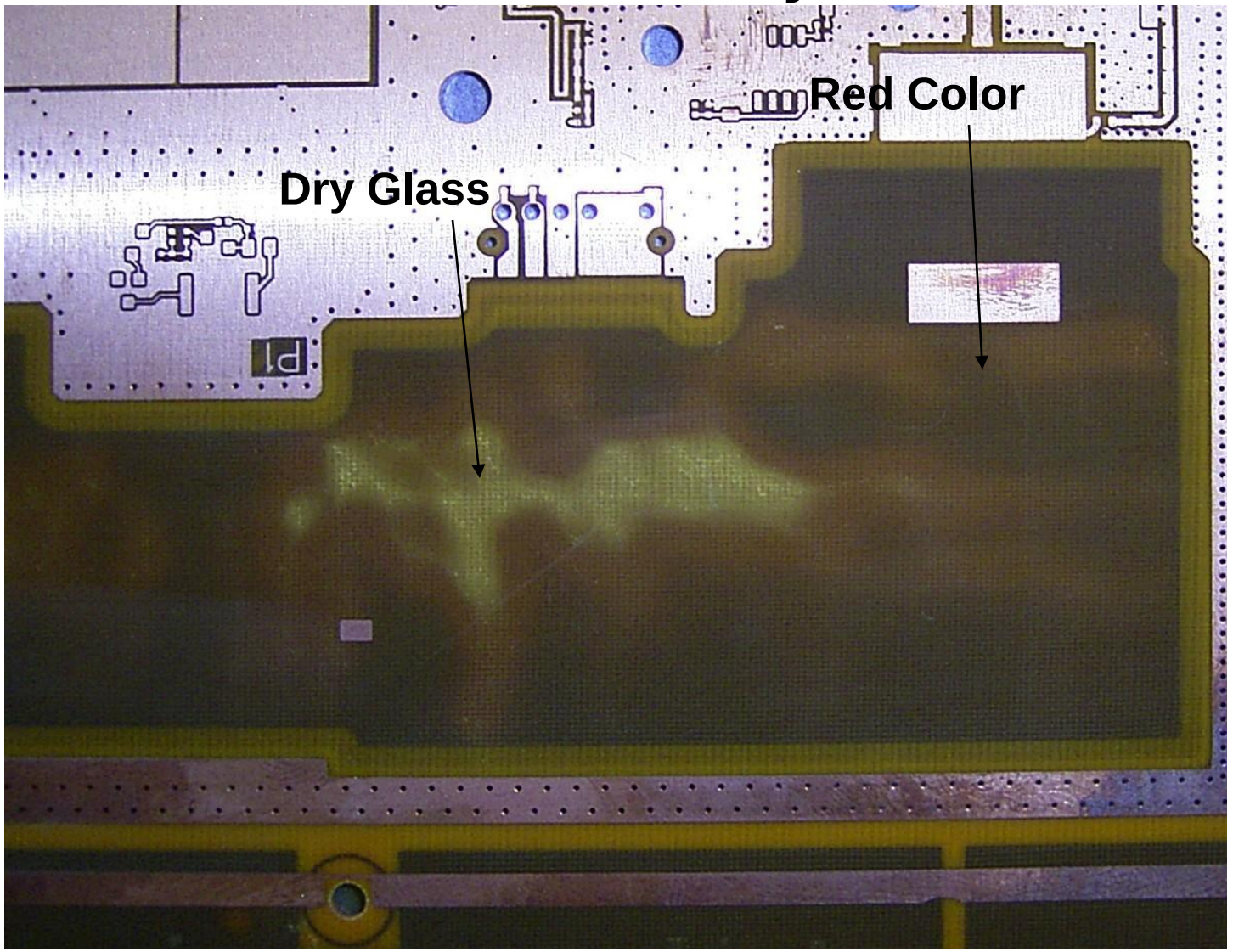
Abstract

- Two primary failure modes from trapped moisture:
- Premature resin decomposition from incomplete resin cross-linking.
- Explosive vaporization during high temperature thermal exposure.

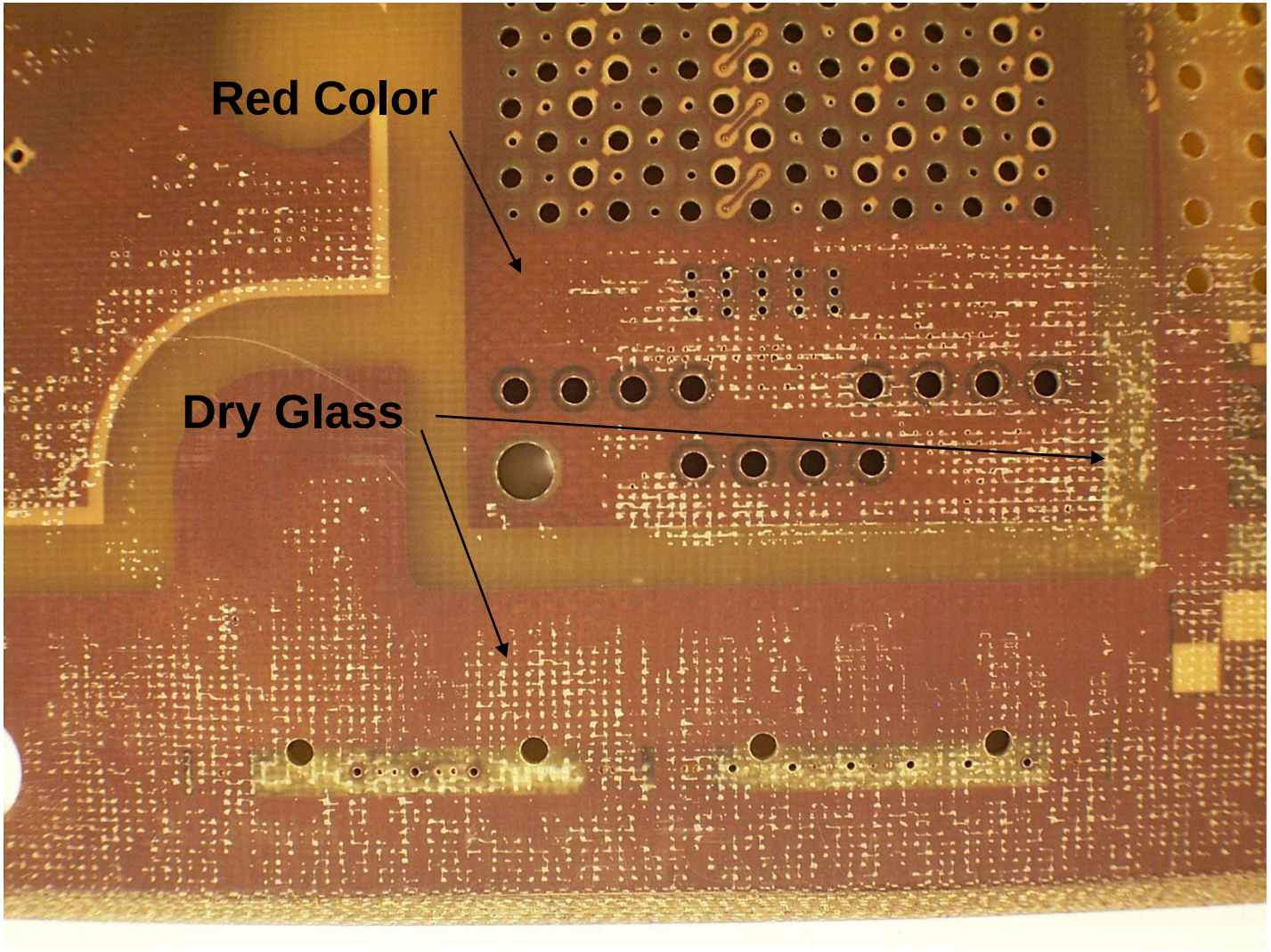
- Prior papers have well documented negative effects of trapped moisture before lamination including:
  - Red color during lamination
  - Reduced thermal reliability
  - Increased high frequency signal loss
  - Increased CAF

Typical Moisture Problems

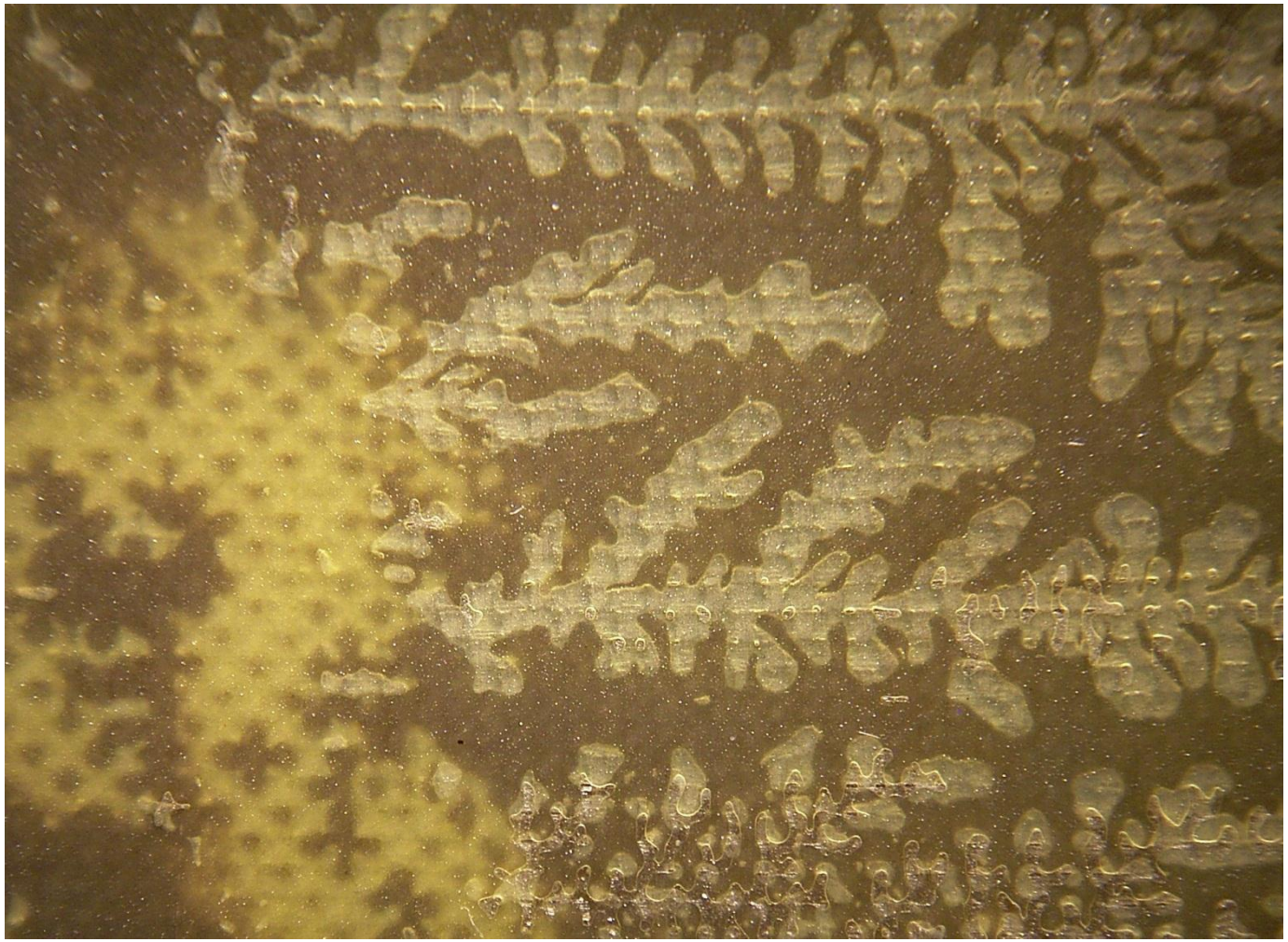
Red Color and Dry Glass



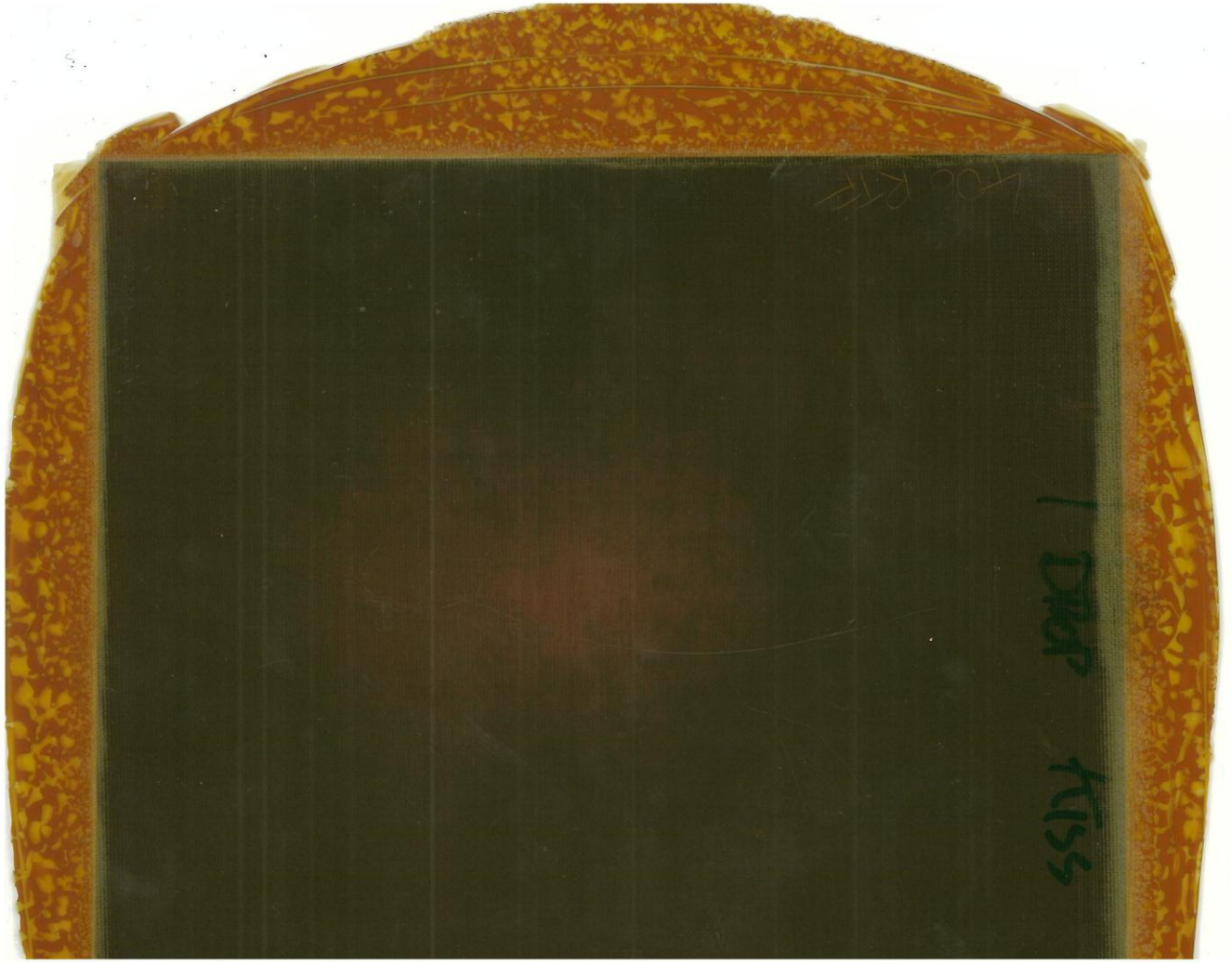
Red Color & Dry Glass



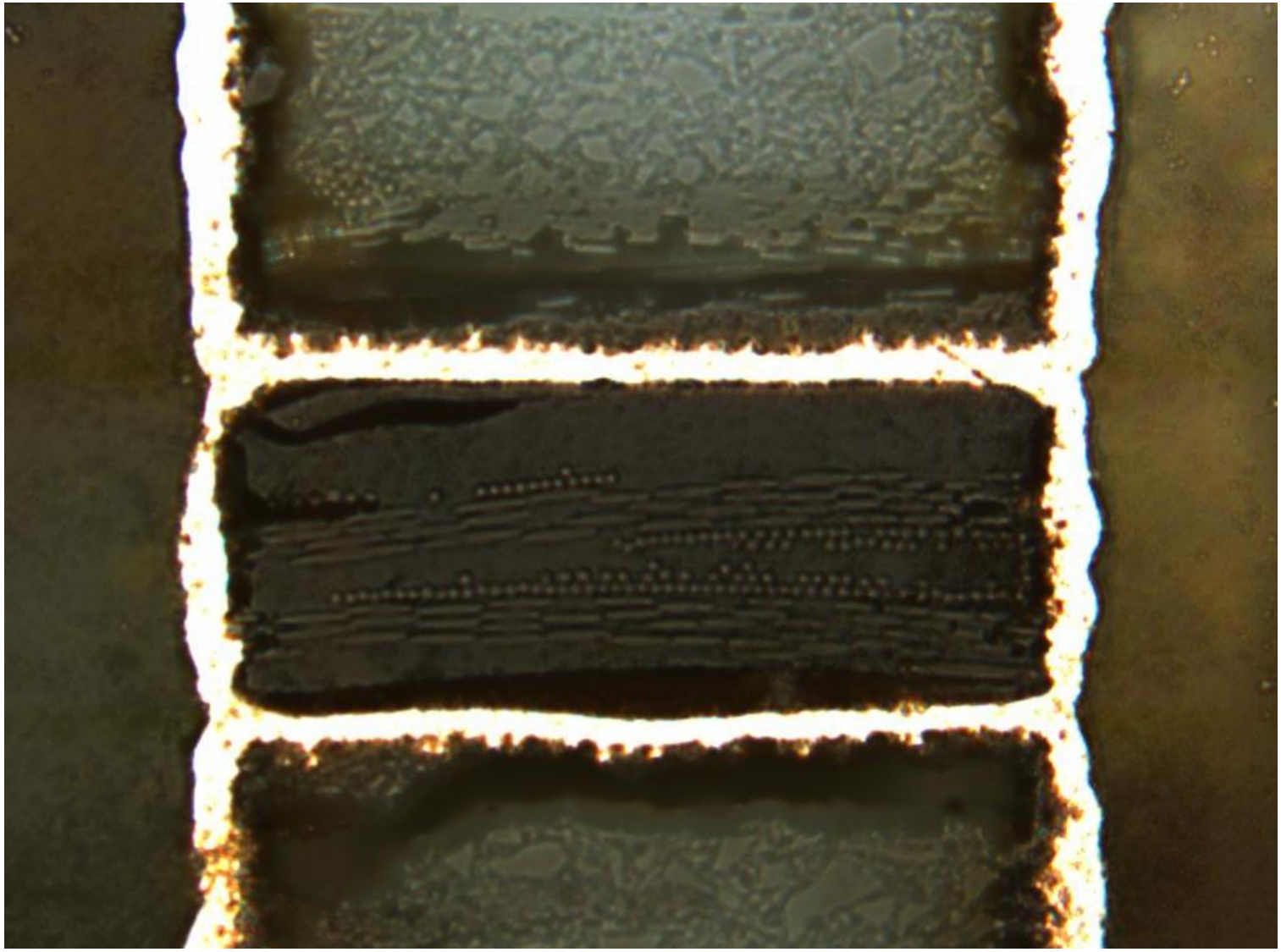
Dry Glass from Moisture



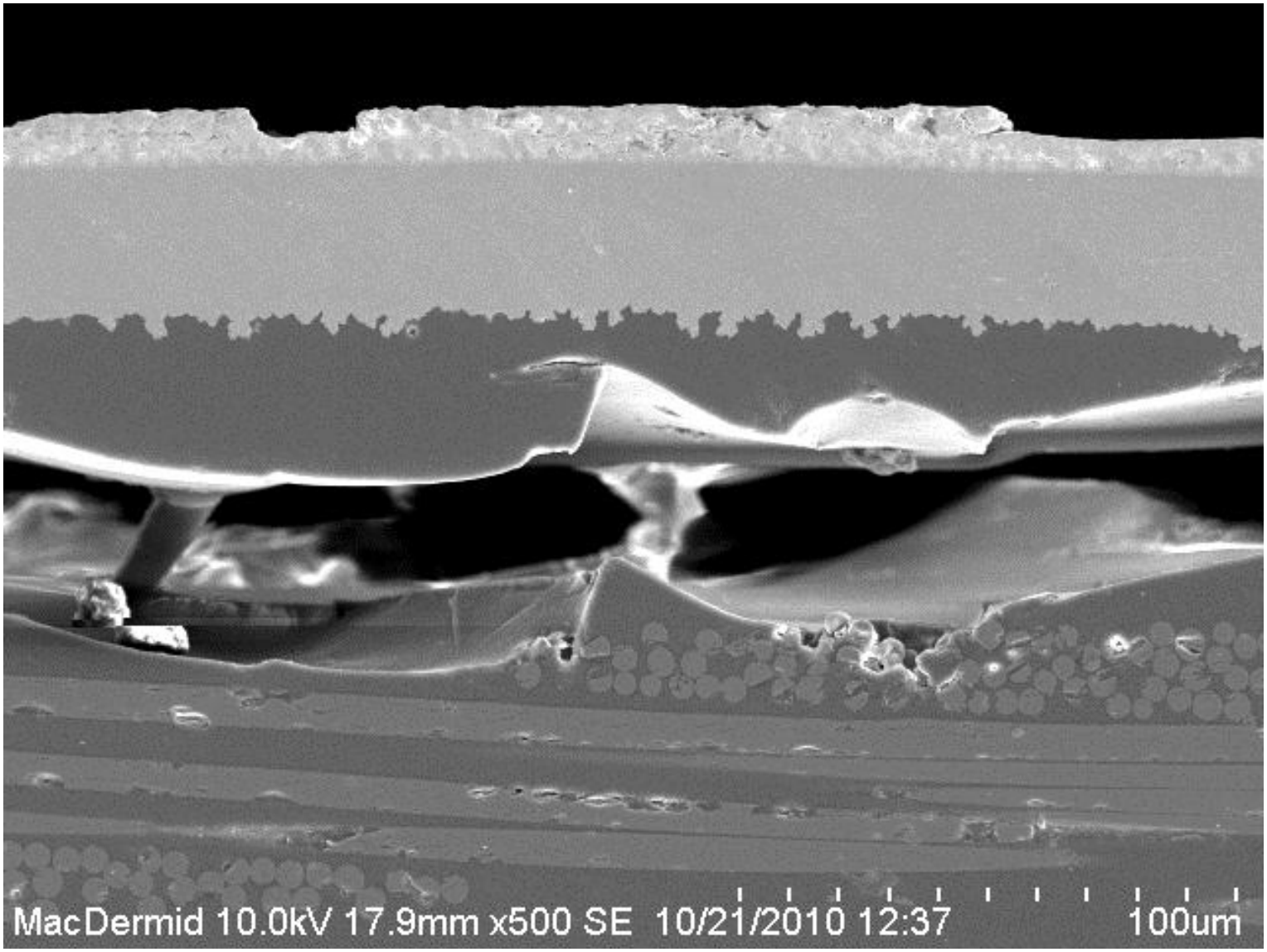
Excess Foamy Resin Bead



Delamination After Reflow



Delamination After Reflow



Problems with Non Dicy Materials

- Customer experience with red color after lamination and premature delamination with 180 Tg PN type.
- Red color switch was increased lamination cure temperature, from 185^0C to 200^0C.
- Reduced cure temperature, Pre vacuum and Kiss had no benefit with introduced moisture reliability test results.

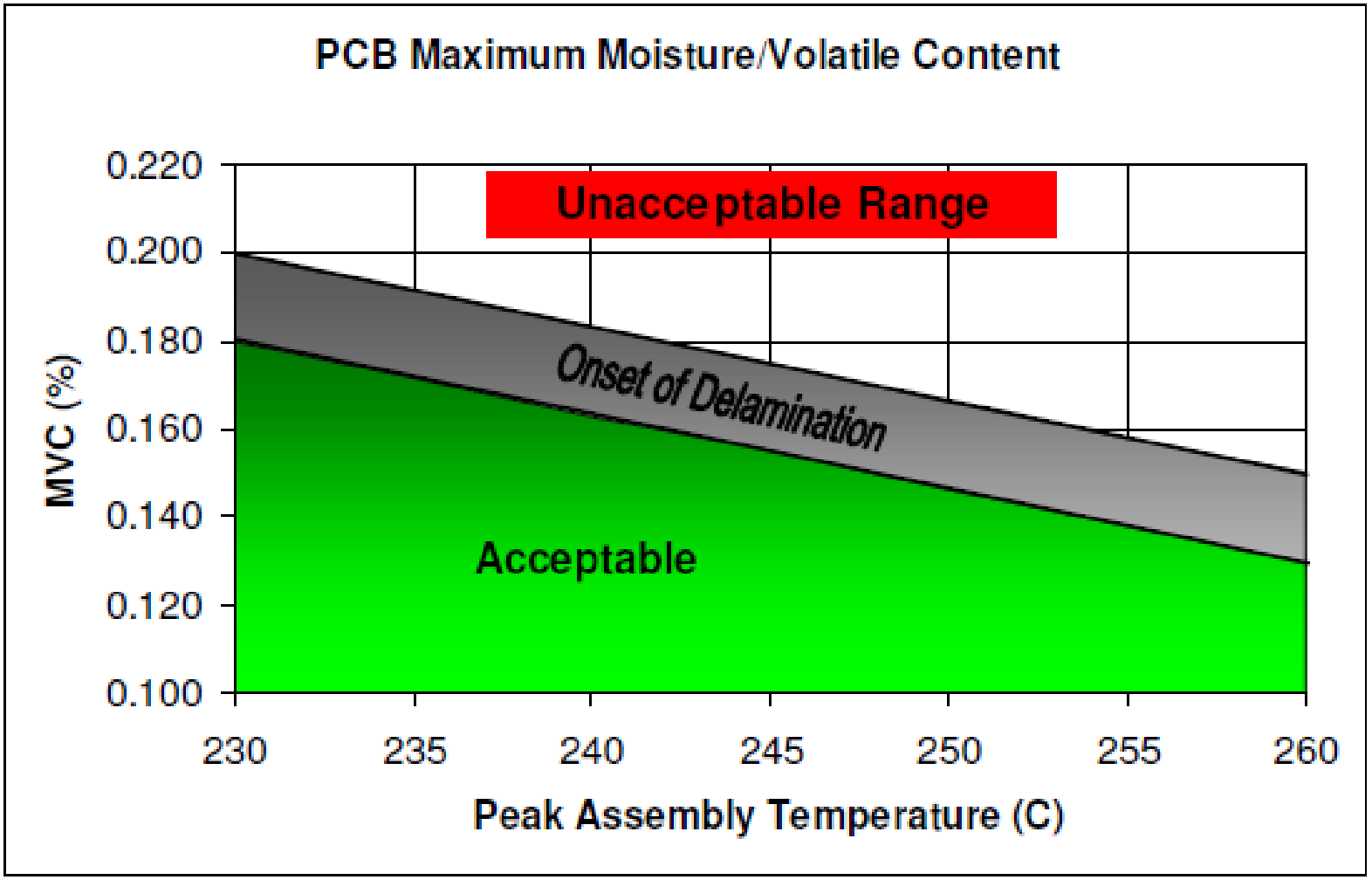
Prepreg Moisture Control

- Controlled storage conditions per supplier.
- Sufficient time for equilibration coming from cold storage.
- Minimize storage time of any open prepreg bags.
- Re-seal open bags with desiccant.
- Prepreg Dry boxes and Vacuum desiccation.

Inner Layer Moisture Control

- Prevent absorbed moisture after DES through Lay-Up.
- Stage In-process Inner Layers in a controlled environment.
- Minimize time in uncontrolled areas including hallways, plating areas etc.
- Goal is to maintain < 0.15% maximum Moisture/volatile content.

Stay Green!


PCB Maximum Moisture/Volatile Content
Unacceptable Range
Onset of Delamination
Acceptable
MVC (%)
0.220
0.200
0.180
0.160
0.140
0.120
0.100
230
235
240
245
250
255
260
Peak Assembly Temperature (C)

Inner Layer Moisture Control

- Maintain horizontal dryer temperature at 65^0C -75^0C.
- Additional drying capacity may be needed to fully dry plated sub assemblies.
- Best Practice – Bake for 30-60 minutes at 120^0C, with minimum hold before lamination.

Moisture Sensitivity

- Testing of various materials
  - Introduced Moisture
  - Evaluate the effect of using Pre-Vacuum and low temperature, low pressure “Kiss” step in lamination.
  - Evaluate for red color formation and high temperature reflow cycles to delamination.

Material Moisture Sensitivity Test

6 Non Dicy cured materials.

1. 150^{0}C TG Halogen Free
2. 180^{0}C TG Phenolic FR 4
3. 200^{0}C Multifunctional FR 4
4. 170^{0}C TG High Performance
5. 180^{0}C TG Low Loss
6. 200^{0}C TG High Speed

Method

- 0.05 ml of DI water introduced before lamination using 9” X 9” format
- Test with & without a Pre-Vacuum & Kiss step.
- Pre-vacuum at 28 cm/Hg for 20 minutes, platens open.
- Kiss Step - Platens closed at 5 psi, 30 minutes at 40C, full vacuum

Moisture Sensitivity Evaluation

- Red color after lamination.
- High Temperature Lead Free Reflow cycles to delamination.

Red Color Sensitivity Results

Material	No Pre-Vacuum/Kiss	Pre-Vacuum/Kiss
1	NO	NO
2	YES	NO
3	YES	NO
4	YES	NO
5	YES	YES
6	YES	NO

270^0C Reflow Cycles to Delamination

Material	H_20	H_20 + Kiss	No H_2O
1	3	4	6
2	8	9	14
3	>20	>20	>20
4	1	7	>20
5	>20	>20	>20
6	4	6	15

Summary

- Premature delamination can occur without red color.
- Pre-Vacuum + Kiss step has some improvement, #4 was most improved.
- Material #4 appears to be the most sensitive.
- Materials 3 and 5 appeared to be least affected by introduced moisture

Baking Before Lamination

- Testing with three prepreg materials
  - Baking at 120^0C and 150^0C.
  - Up to 6 hours, exposed to air.
  - Evaluate for peel strength loss before and after 6X 10 seconds solder dip at 288^0C.

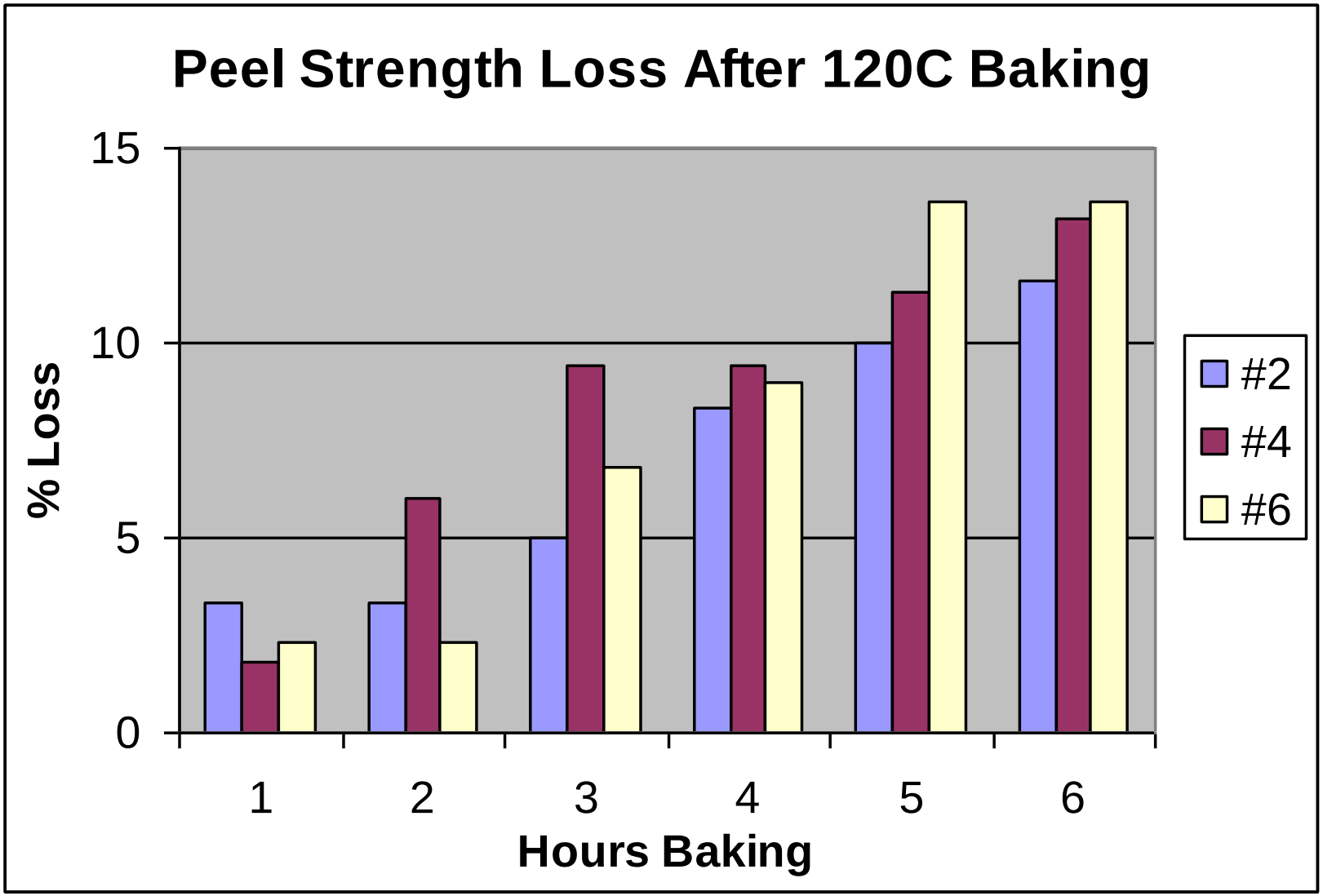
Baking Before Lamination

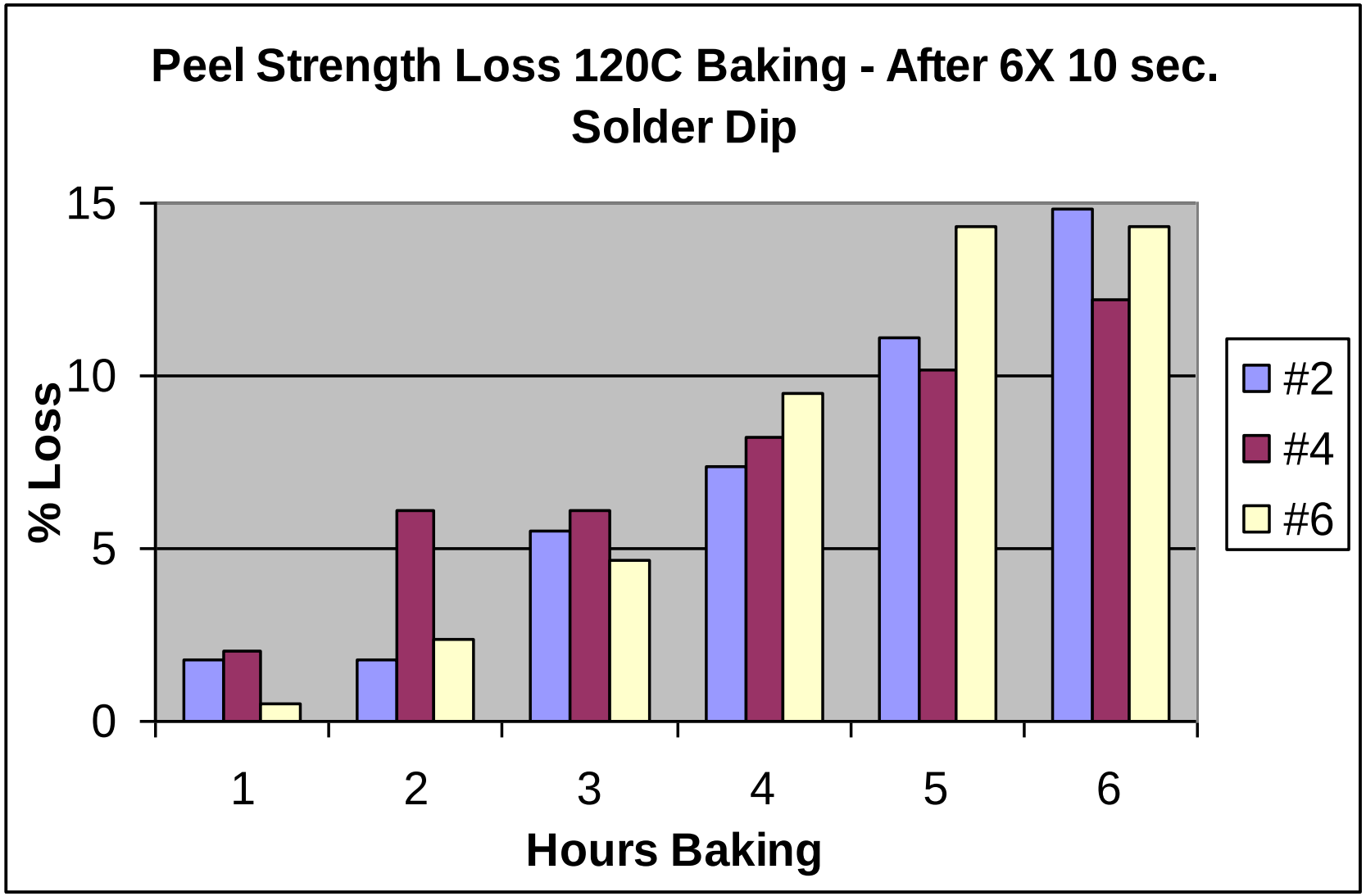
- Bake copper foils after Oxide Alternative for up to 6 hours at 120^{0}C and 150^{0}C.
- Evaluate peel strength on 3 prepreg materials, before and after 6X 10 seconds solder dip at 288^{0}C.

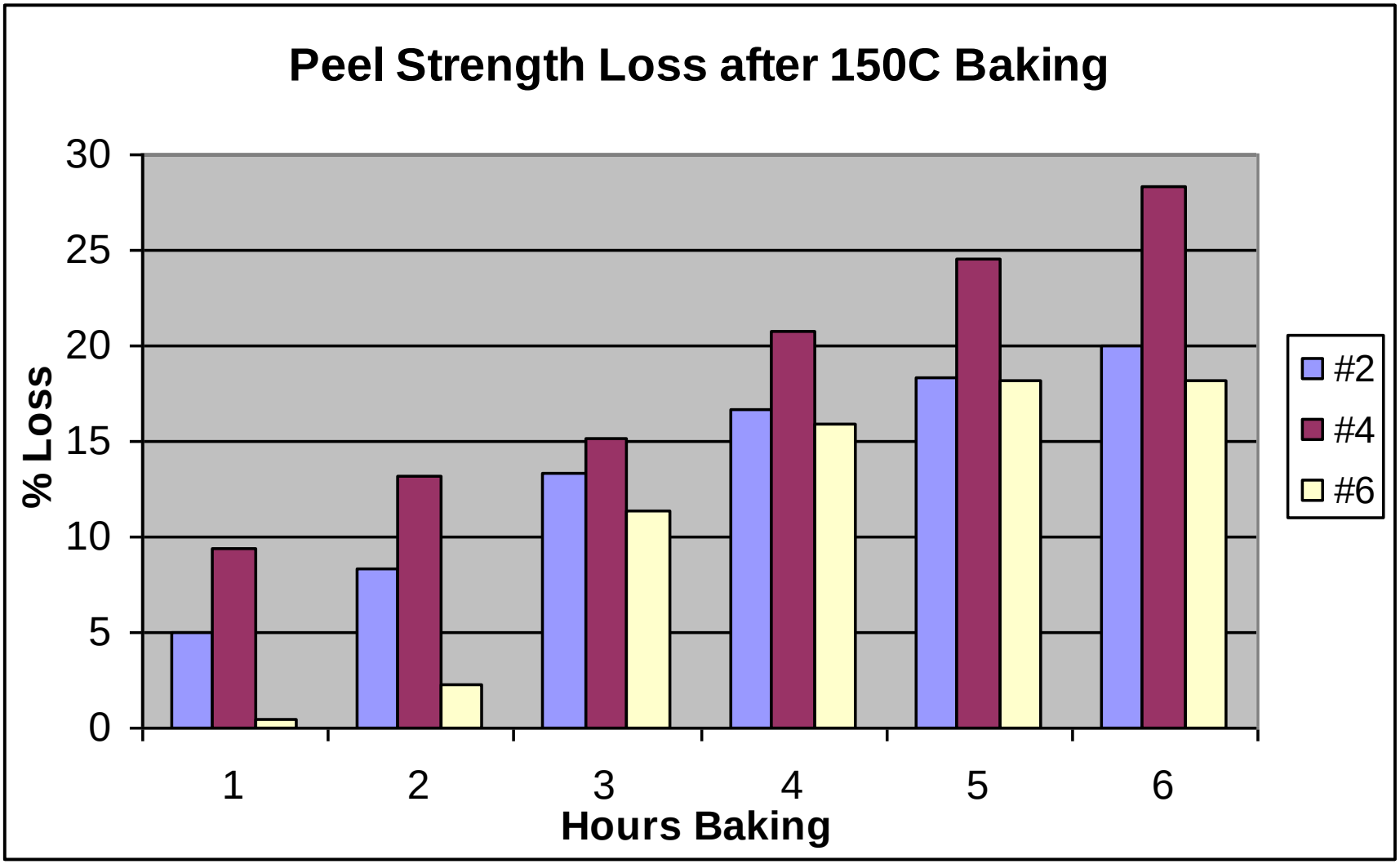
  #2 - 180^{0}C TG Phenolic FR 4

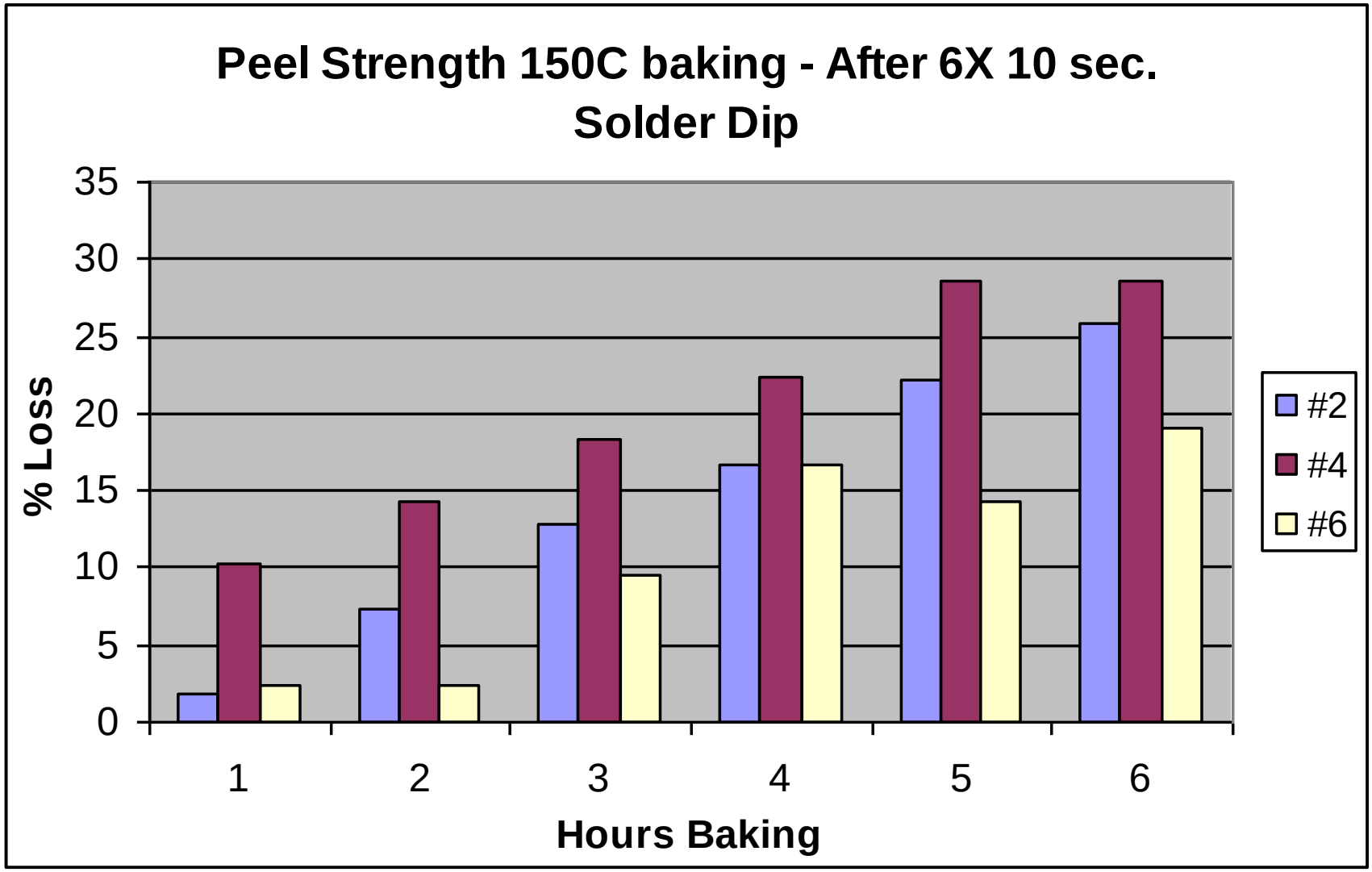
  #4 - 170^{0}C TG High Performance

  #6 - 200^{0}C TG High Speed


Peel Strength Loss After 120C Baking
% Loss
15
10
5
0
1
2
3
4
5
6
Hours Baking
#2
#4
#6


Peel Strength Loss 120C Baking - After 6X 10 sec. Solder Dip
15
10
5
0
% Loss
1
2
3
4
5
6
Hours Baking
#2
#4
#6


Peel Strength Loss after 150C Baking
% Loss
30
25
20
15
10
5
0
1
2
3
4
5
6
Hours Baking
#2
#4
#6


Peel Strength 150C baking - After 6X 10 sec.
Solder Dip
% Loss
35
30
25
20
15
10
5
0
1
2
3
4
5
6
Hours Baking
#2
#4
#6

Baking Results Summary

- 150C has greater loss of Peel Strength than 120C.
- 120C baking had 3.3% maximum loss after 1 hour, 6% after 2 hours.
- 150C baking had 10% maximum loss after 1 hour and up to 14% after 2 hours peel.
- Extended baking at 150C can result in up to 20% loss after 4 hours and 28% loss after 6 hours

Conclusions

- Results confirm recommendation for moisture removal bake without significant loss of the oxide alternative bond integrity
  - 30 to 60 minutes at 120C - 130C
- Baking at 150C for > 1 hour is not recommended after Oxide Alternative

Customer Experience

- SE Asia customers add dryer section(s) to existing lines.
- Many customers now bake all materials before lamination.
  - Stack bake 1.5 cm high typical.
- Some bake only specific moisture sensitive materials, including Halogen Free, High Speed and all sub-assemblies.
- Maximum hold after bake of 4 to 8 hours in a controlled environment.

Baking SBU plated Sub Assemblies

- Extended baking of plated sub-assemblies at 150C before Oxide Alternative process removes moisture and all volatiles from hole fill resin and plated copper.
- Most delamination is seen on outer-most layers, typically from Z axis expansion and/or outgassing.
- Plated copper may require baking to anneal or re-orient the copper crystals for sulfuric/peroxide micro-etch or Oxide Alternative.

Baking SBU plated Sub Assemblies

- Need good rinsing and drying after copper plate to prevent severe oxidation after baking.
- Color and appearance of copper after 150C baking indicates the quality of rinsing and drying. Oxidation should be uniform.
- Use micro-etch to remove Cu oxidation before Oxide Alternative.

Conclusions

- Inner layers and Prepreg must have < 0.15% moisture before lamination to survive Lead-Free Reflow.
- Some materials more sensitive to moisture.
- Effects of trapped moisture during lamination are typically irreversible.
- Pre-vacuum and “kiss” lamination helps, but not 100% effective.

Recommendations

- Prepreg
  - Storage in a controlled environment.
  - Equilibration before opening sealed bags.
  - Add desiccant and re-seal any opened, partially used bags.
- Inner layers
  - Hold only in controlled areas after DES.
  - Bake before lamination.
  - Use pre-vacuum with ‘Kiss” step

References

1. R. Massey, A. Lion, R. Haidar “Study of Red Spot Phenomenon In Oxide Alternative, Leading to Improved Trouble Shooting” Proceeding from 12th. Electronics Circuits World Convention, 2011
2. L. Ma, B Sood, M. Pecht “Effect of Moisture on Thermal Properties of Halogen-Free and Halogenated Printed Circuit Board Laminates.” IEE Transactions On Device and Materials Reliability, Vol. 11, No 1, March 2001
3. L. Kumosa, B. Benedict, D. Armentrout, M Kumosa “Moisture Absorption Properties of Unidirectional Glass/Polymer Composites Used in Composite (Non-Ceramic) Insulators” In Press, Composites, Part A 2004
4. K. Knadle “Failure mechanisms in Lead-Free Laminates” Printed Circuit Design and Fab, November 2009
5. P. Reid “Dielectric Performance in Lead Free Assembly” Printed Circuit Design and Fab, March 2009
6. M. Gay “MSL Handling and Storage of PCBs & Laminates for Lead Free Assembly” IPC India 2009

Thank You!