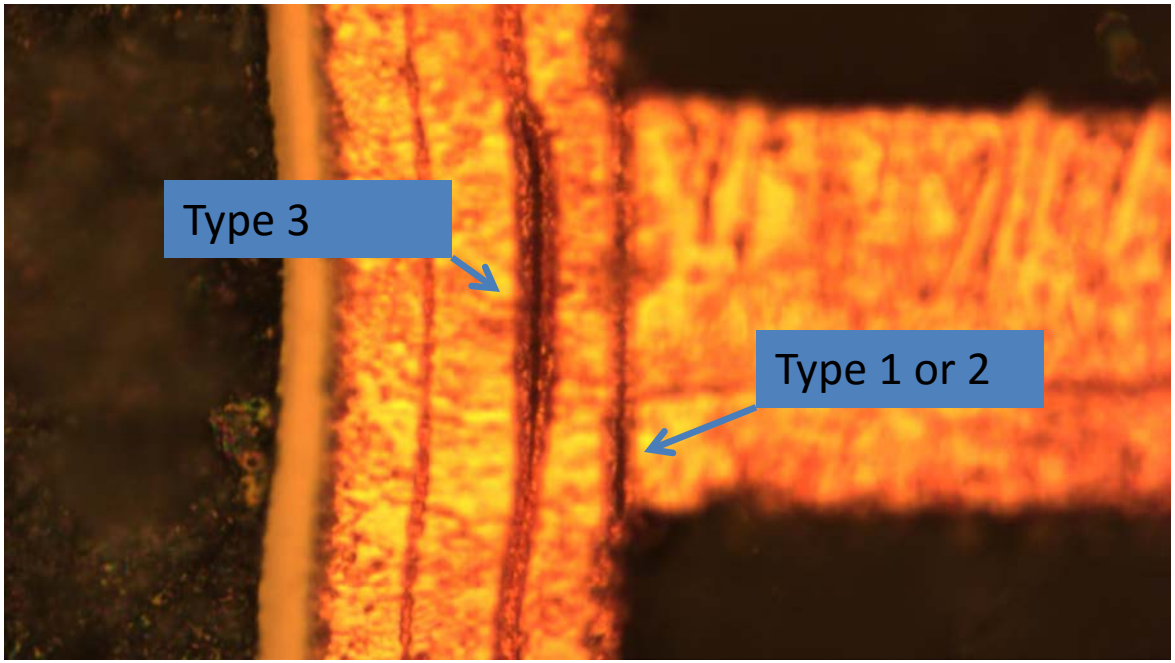
# ICDs (InterConnect Defects) What are they? Where do they come from? How can we make them go away?

Doug Trobough
Suixin Zhang

# Definition of ICD

- **ICDs are any defect that occurs adjacent to the innerlayer copper post**
- **Some common types are smeared resin, hole debris, and post separation**
- **ICDs are broken up into 3 categories**
  - Type I – Between inner layer copper and electroless copper
  - Type II – Between electroless copper and electrolytic copper
  - Type III – Elsewhere in copper
- **We will only refer to Type I**

# Example of ICD types

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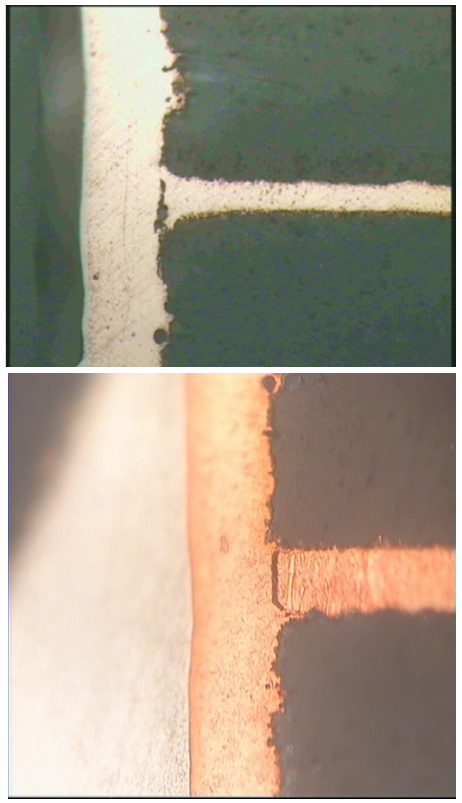
# Categorizing Type 1 ICDs

- **Debris type**
  - (Debris interfering with interconnect bond
    - Drill debris
    - Smear
    - Dielectric filler powder
- **Separation type**
  - (Separation of interconnect bond)
    - Copper cleanliness
    - Drill work hardening
    - Rinsing residue
    - Poor electroless copper quality
- **This approach helps communicate root cause**



# Why do we care?

- **Type 1 Debris type ICDs are not closely related to finished product defects**
  - Fail IPC and Military specifications – Product generally can't be shipped
  - Have been tested at multiple companies without exhibiting significant impact on through hole reliability
- **Type 1 Separation type ICDs are closely related to the formation of open circuits in assembled PCB's.**
  - Valid reliability concern
  - Specification failure

# ICD debugging comments

- **In general, not enough work is done to determine what type of ICD is occurring**
- **Dominant response to ICD is to increase desmear level**
  - Works on smear and debris
    - But is not necessarily the root cause
  - Can make Separation type ICDs worse
- **Desmear process changes by PCB fabricators are common, but very hesitant to change electroless copper parameters**

# Debris Type
## Where do they come from?

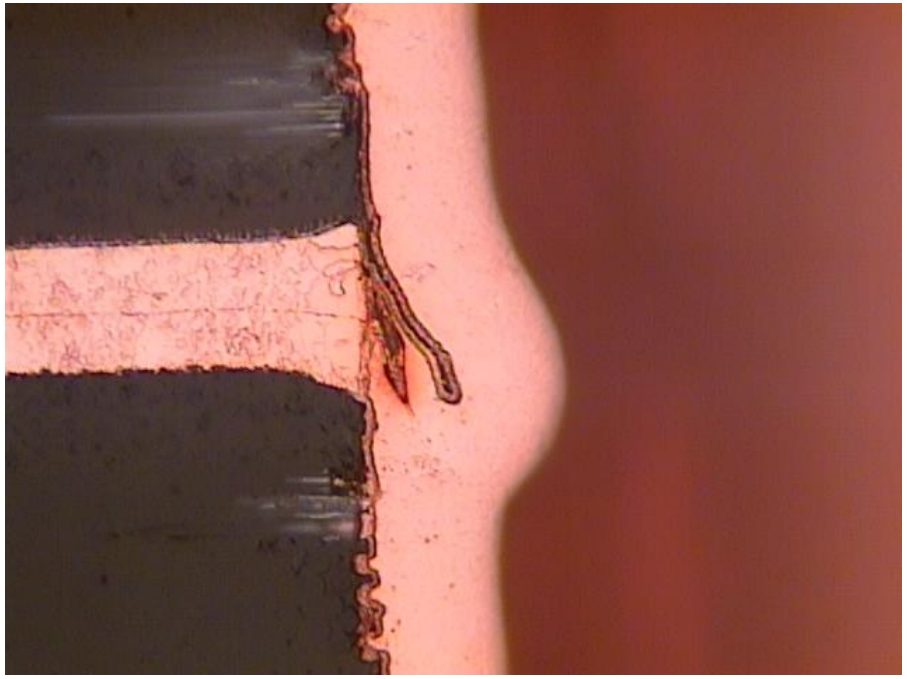
- **Direct Cause**
  - Debris generated during the hole drilling process coats (or sticks to) the drilled hole wall
  - Debris is not entirely removed during post drill cleaning – Primary cleaning is called desmear process (or smear/debris removal processing)
  - Debris interferes with formation of “flawless” interconnect interface
- **Debris type ICDs are visible as built, and do not require thermal stress to occur.**

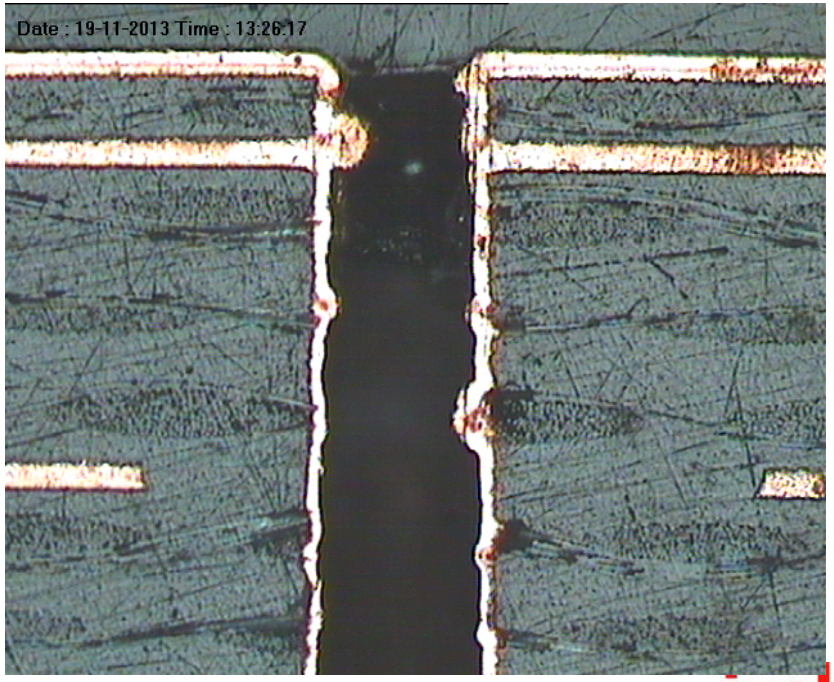
# Primary Debris Type ICD causes

- **Drilling**
  - Hot drill bits do not drill cleanly and create more debris, that tends to be adherent to the copper and hole walls
  - Worn drill bits tend to heat up easier and have the same appearance as Hot drill bits.
  - Sub-optimal drill parameters or drill bit design
- **Desmearing**
  - Many low Dk, low Df materials are more chemically resistant than standard epoxy (FR-4) type materials
    - More aggressive desmearing is required
      - Plasma etching processing is effective on these material
      - Enhanced chemical desmear processing may be needed
      - Enhanced process control tools may be required

# Contamination Type Debris

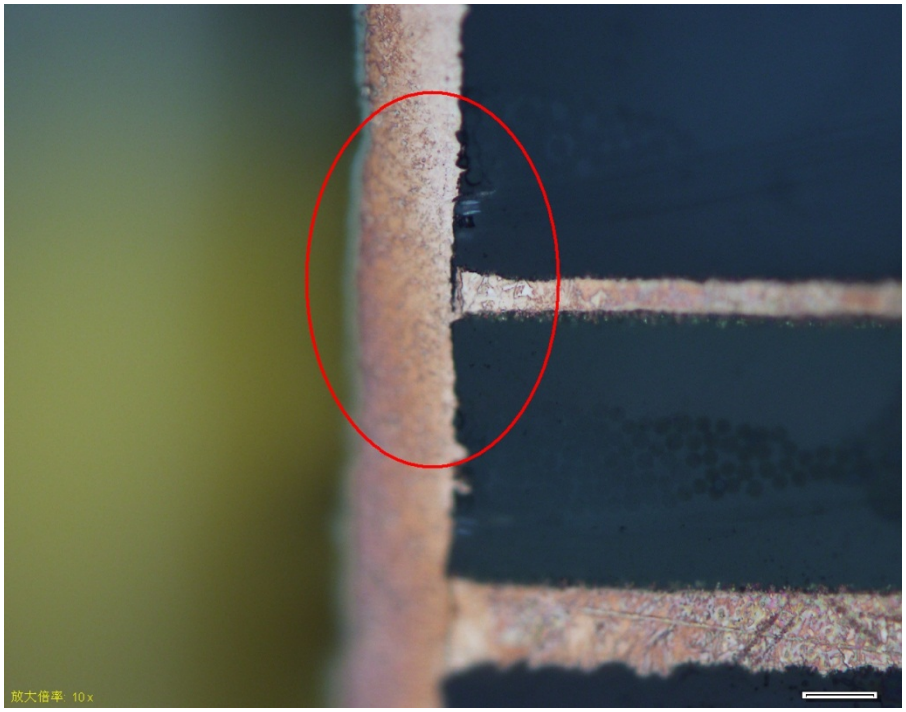
- **This type has gotten the most attention in Asia**
- **Main cause**
  - Powdery debris after drilling

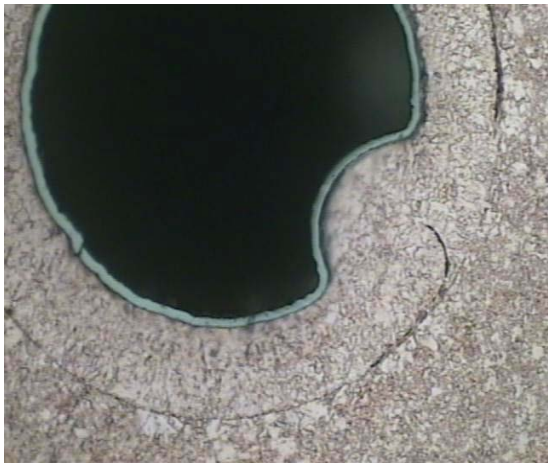




# Examples of Debris Type

- **Note lack of wicking and glass protrusion**
  - Bad plasma or poor chemical desmear



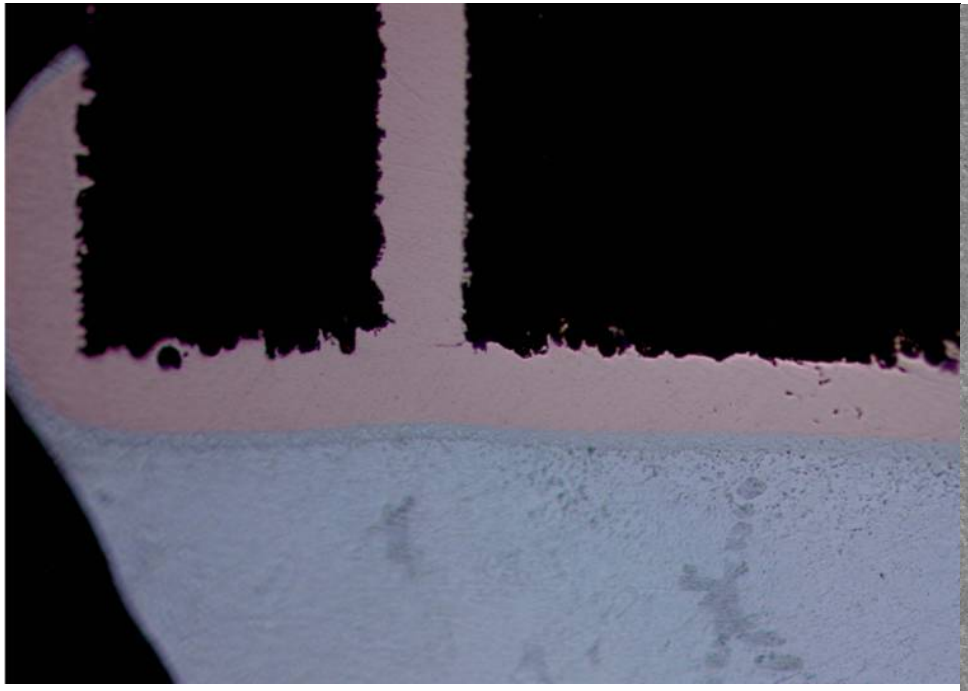
# Separation Type ICDs
# Where do they come from?

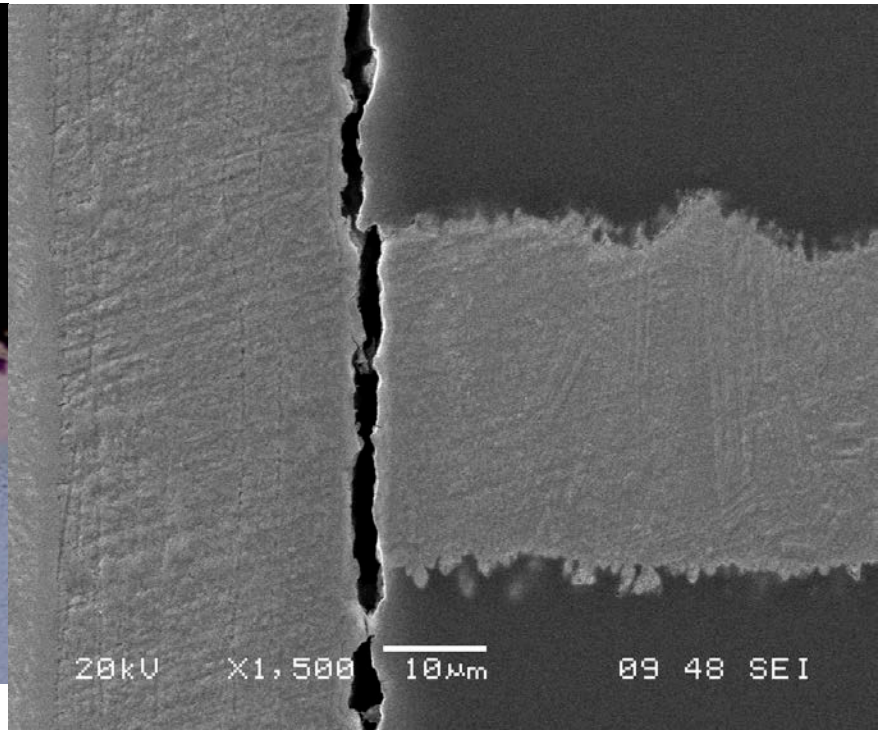
- **The primary characteristic of this failure type, is that a copper to copper bond is pulled apart during thermal exposure**
  - Normally visible only after thermal stress or reflow
- **Two modes**
  - Low strength – Copper plating bond is too weak to handle normal stress levels during thermal exposure
  - High stress – Design and material related. Additional stress is concentrated on specific interconnect locations

# Primary Separation Type ICD causes

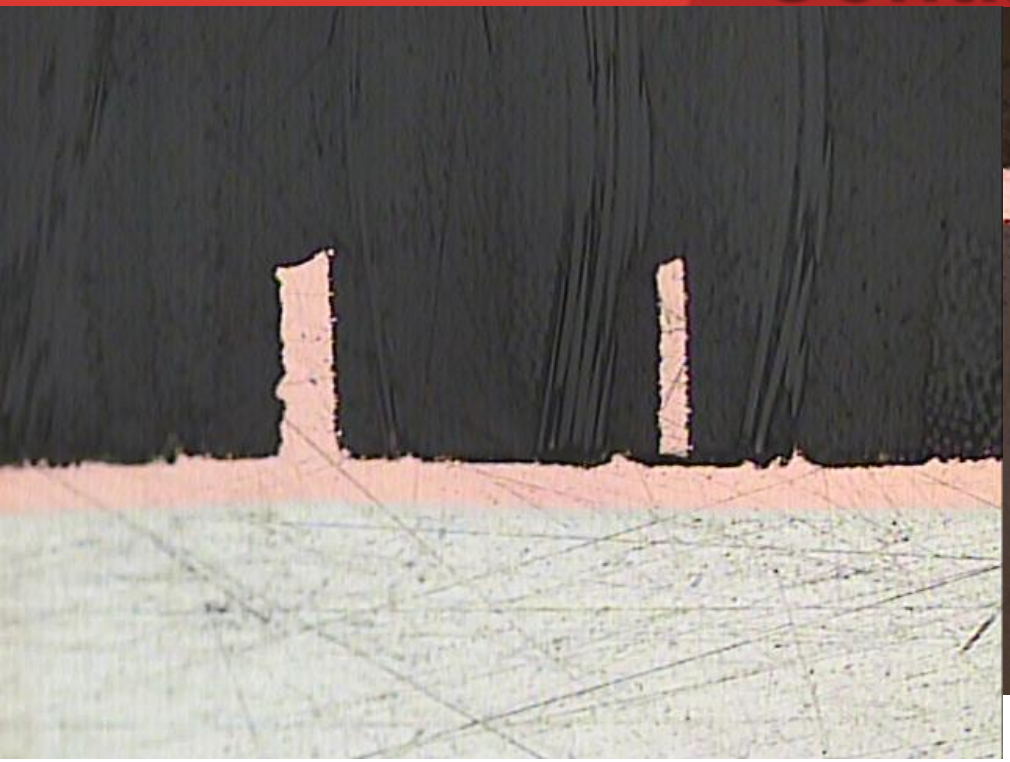
- **Low bond strength**
  - Poor plating adhesion to the hole wall
  - Lack of good bonding surface in hole wall
  - Lack of clean oxide free copper surface in the hole wall
  - Electroless copper properties are poor
- **High Stress during thermal exposure**
  - High CTE material
  - Design resin content
  - Very thick copper plating
  - Nickel plating
  - Larger hole size
  - Board thickness
  - Interconnect pad configuration

# Examples of Separation Type ICDs

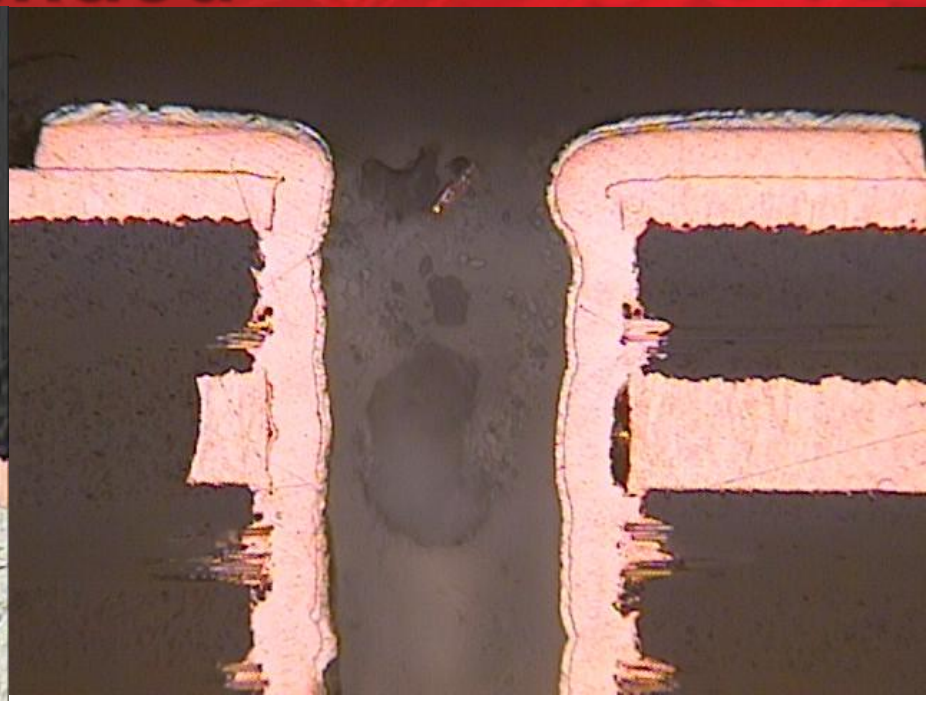




# Examples of Separation Type ICDs Continued



Post Separation Type



D-Void Type

# Getting Rid of ICDs

- **ICD formation is strongly related to two key factors**
  - PCB fabricator processes
  - Raw material type
- **Capable and consistent processes in drilling is best approach**
  - Avoids creation of ICDs
- **If ICDs are found follow this path**
  - Review samples and findings from problem orders
  - Identify the type of ICD
  - Follow troubleshooting method for this type of ICD

# Debris ICD Type Troubleshooting Drilling

- **Drilling generates the debris that causes most of this type of ICD.**
- **Get drill parameters under control**
  - Good vacuum levels at drilling
  - Correct chip load
  - Correct cutting speed
  - Bits in good shape, not worn or damaged
- **Beware of combinations of high cutting speed and low chip loads**
  - This combination creates high heat levels and more debris
- **Significant copper nailheading is commonly found with Debris based ICDs**
  - Reducing nailheading helps reduce debris ICDs
- **Assess  drilling quality using SEM of half holes**

# Debris ICD Type Troubleshooting Desmear

- **Desmear removes the debris generated by drilling – Good desmear is critical for consistent results**
- **If using Plasma Etching, Get weight loss under control – Efficient etching**
  - Temperature control is the main issue
    - Etch rate rises with time if panels are cool at the start
    - Hot panels may have overetch and plating adhesion issues
  - Dry boards before plasma etching – water vapor from dielectric reduces plasma etch effectiveness
  - Measure etch rate on coupon with drilled holes, not surface coupons
    - Weight loss of 30mg/DM2 in holes, or 45-50mg/DM2 for surface coupons is a good target
- **PCB Fab's with good Plasma Etching process have very little ICD issues, when plasma etching is used – Best Practices**
  - Dry and preheat panels, load panels "warm-hot"
  - Control weight loss amount and even distribution of weight loss over full load
- **SEM's of half holes is the best tool to characterize Plasma Etching process effectiveness, along with weight loss control.**

# Debris Debugging
# Chemical Desmear

- **Chemical desmear has two functions**
  - Effective at washing out debris
  - Removes resin – Removal rate is very dependent on dielectric resin type
- **Chemical desmear issues**
  - Sweller type
    - Some materials not compatible with all sweller types – particularly NMP type
  - Weight loss
    - Similar to plasma etching, characterize and keep this process under control
  - Chemistry control
    - High $MnO_2$ levels can cause debris to form
  - Agitation, rinsing, ultrasonics
    - Very important on chemical desmear lines
    - Permanganate bathes are very viscous so agitation is critical
    - Good performing PCB fabricators have very good agitation

# Separation ICDs
# Strength of Interconnect

- **Creating a strong connection between the innerlayer copper and the electroless copper layer is the best way to avoid ICDs**
- **The following is a partial list of factors affecting interconnect strength**
  - Good metallurgical copper bond
    - Clean copper, no chemical residues
    - Oxide free copper surface
    - Good grain structure on copper foil
  - Strong electroless copper
    - Appropriate thickness
    - Controlled deposition rate (not to fast)
    - Good grain structure
  - Good hole wall adhesion
  - Copper foil thickness
    - Thicker is better
  - No localized drill damage

# Separation Type ICD Debugging Strength of bond

- **Determine copper etch weight loss**
  - Best over 30u” (0.75 um) removed in holes
- **Use good water quality on electroless copper line rinsing**
  - Over desmear can also lead to rinsing issues
- **Improve hole wall adhesion**
  - Good desmear, with adequate texture
  - Don’t over desmear or use too high temperature desmear

# Separation Type ICD Stress Causes

- **High z-axis expansion**
  - High resin content
  - Low TMA Tg
  - High expansion material
- **Poor copper hole wall adhesion**
  - Puts strain on interconnects, instead of distributing through out hole wall
- **Design factors**
  - Tight grid hole patterns
  - Large hole size
  - Pads only on layers 2 or N-1
  - Board thickness
  - Localized resin content (regions requiring high resin fill)
- **Solder shrinkage in holes**
  - Pulls copper away from hole wall
- **Uncontrolled or over-temperature exposure**
  - Poorly controlled solder fountain rework (example)
- **Constraining surface finishes**
  - ENIG, Electrolytic Nickel/Gold

# Separation Type ICD Debugging Stress Reduction

- **Process to achieve good hole wall adhesion**
  - Allow options for single ply and heavier glass styles
- **Reduce resin content in the stack-up**
- **Do not use nickel plating**
- **Avoid design factors**
  - As noted on previous slide

# General Commentary

- **ICDs are rare in the US and Europe**
  - Long history of Military and High Reliability electronics has resulted in good processing practices
- **ICDs are PCB process related**
  - Strong processes with good process control do not see significant problems
- **Some material types are more likely to have ICDs**
  - Materials with inorganic fillers, and more chemically resistant resin systems
  - Require tighter processing windows, or extra desmear steps, to achieve excellent results
  - Plasma etching is more common on these types

# Summary

- **ICDs are a significant PCB industry issue, primarily in Asia.**
- **High performance material systems are more likely to have ICDs**
- **Many fabricators have consistently good results, no ICDs**
  - Use best practices at drilling and desmear
- **ICD type identification, good engineering, and good controls have been effective at eliminating ICDs**
- **Isola and other companies continue to perform Research into the causes of ICDs**
  - Working to make the system more robust