ARLON
TECHNOLOGY ENABLING INNOVATION

APPLICATION NOTES

# Drilling Defects: Causes and Solutions

**Nailheading:**

Nailheading is the distortion of the copper inner layer at the hole wall, this distortion takes the form of a "Nailhead". There are several types of nailheads, the most common type seen on small hole diameters is a thermomechanical nailhead. The thermo-mechanical nailhead is produced by excessive heat and the drill bit pushing and pulling the copper in each direction the drill bit travels. Drill sizes above 0.0292" diameter are susceptible to both thermomechanical and mechanical nailheading. Mechanical nailheading only is characterized by a one directional nailhead. This nailheading is usually accompanied by a heavy resin smear over the copper.

*Potential Causes:*

1. Incorrect infeed.
2. Incorrect spindle RPM.
3. Incorrect retract rate.
4. Undercured resin.
5. Drill bit clogging.
6. High temperature elongation copper / Number of copper layers.
7. Entry or backer material.

*Corrective Action:*

1. Determine "type" of nailhead, single sided nailheading or bi-directional nailheading.
2. For Single sided nailheading: Reduce infeed rate, or increase RPM. For Bi-directional nailheading, reduce RPM or increase infeed rate.
3. On small diameter drills, retract rates may be reduced.
4. Undercured "B" stage will soften and not provide mechanical support for the copper, and will allow nailheading.
5. Check the drill bit for clogging. Clogging of the flutes can be caused by drill bit design, aluminum entry sticking to the drill flutes, under cured resin, backer material or poor vacuum removal of drill debris.
6. High temperature elongation copper foils will increase nailheading, the higher the tensile elongation of the copper, the more severe the nailheading will be under conditions that would causenailheading.
7. Some types of entry and backer material will adhere to the drill bit flutes causing hole wall quality problems.

**Smear:**

Smear is a thin layer of resin transferred from the base material of the hole wall during drilling, that covers the exposed edge of the inner layer pad (land). Thermal mechanical smear that is created by excessive heat (drill friction) and is clear in appearance. Purely mechanical smear is a heavier coating over the inner layer land with a color similar to the resin system being used and may be related to the same process issues that result in nailheading.

*Potential Causes:*

1. Undercured resin.
2. Excessive spindle RPM.
3. Excessive infeed during drilling.
4. Too low infeed vs RPM (generates heat).
5. Drill depth into backer.
6. Dull drill/chipped drill.
7. Under cured resin in backer material
8. Incorrect smear removal process.

**Corrective Action:**

1. Verify the press cycle, cure parameters and processing conditions for the lot and material in question.
2. Verify RPM. [Note: The most common practice to determine correct RPM is to calculate RPM for a given drill size- based on a pre-determined surface feet per minute formula. A recommended starting point is 350 SFPM for higher Tg materials such as Arlon supplies.]
3. A very high infeed rate while drilling will create a heavy resin smear over the inner layer copper. This smear will have the same coloring as the base material being drilled. This usually occurs on drill sizes larger than 0.0292”. The infeed rate is probably too high, reduce the infeed in increments of 20% until problem is corrected.
4. Adjust drill depth into backer material to proper level, (1½ times the drill diameter, or the drill point geometry + 0.010”). Excessive drill depth into the backer will create unnecessary heat, resulting in smear.
5. Dull/chipped drills create heat, resulting in smear. An individual drill bit should be retired when recommended wear limit is reached. Chipping can be caused by improper drill bit handling, incorrect infeed rates, or improper entry materials.
6. Under-cured resin in the backer material will transfer to the inner layer conductor. This is a “sneaky” effect, since most fabricators will be aware of the Tg of the product itself, but perhaps not of the backer.
7. Smear removal processes which are too weak or spent will not adequately remove smear. Make necessary additions or increase temperature or time in smear removal as recommended by the chemistry supplier. If using plasma etch back make necessary changes to gasses, power settings and/or time in vacuum chamber to properly remove any smear.

**Resin Fracturing (haloing) Surface:**

Resin fracturing is mechanical damage to resin in the proximity of the hole wall. The damage may be “Surface” or “Hole Wall Fractures”. Surface fractures are visible without the aid of cross section analysis, and will usually be accompanied by disruption of the outer layer copper material. Hole wall fractures occur between conductor layers and usually require cross section analysis for detection and analysis.

Potential Causes:

Surface Fractures

1. Infeed rate too high.
2. Incorrect entry material - Entry material which is soft or thin and will not properly support the drill on entry, allowing the drill to create a burr on the top of the panel which will separate the base copper foil from the resin and create a fracture or crack in the resin.
3. Backer material - If the backer material does not support the PCB properly on exit- the material will be pushed out instead of drilled, creating an exit burr which will usually shows fractures under the copper.

**Hole wall Fractures**

1. Excessive heat or mechanical stress created when high spindle speeds are used with slow infeed rates.
2. The resin is undercured.
3. The drill flute clogs with resin, entry material, copper, or backer material.
4. Wrong backup material.

*Corrective Action:*

1. Adjust infeed rate, reduce in increments of 20% until fracture is eliminated.
2. Change entry material to one which will support the drill on penetration.
3. Change backer material to a harder material. Backer material should be approximately as hard as the material being drilled.
4. Adjust spindle RPM to correct SFPM and change infeed rate to appropriate level.
5. Verify proper laminate cure, if in “B” stage areas, re-bake to specifications adhering to maximum stack height, time at temperature, and cool down cycle.

6. If steps 1 – 5 are completed and OK, flute clogging is caused by;

   a. Entry material (aluminum) sticking to the drill (on small diameters) blocking the path of the drill debris evacuation.

   b. High RPM low infeed rates causes the PCB board resin to get hot and adhere to the drill.

   c. Check Drill design, small diameter drills with insufficient flute volume will clog.

7. Use harder backup material.

**Gouging:**

Gouging is excessive and irregular removal of base material from the drilled hole wall. Gouging may be evident in either the resin rich areas or the glass reinforced areas.

*Potential Causes:*

In resin rich areas

1. Desmear operation too aggressive.
2. Depth into backer material too deep.
3. Under cured material.
4. Clogged drill flute.

In glass reinforced areas

1. Glass etch too aggressive.
2. Incorrect drilling parameters.
3. Chipped drill.

*Corrective Action:*

1. Correct desmear and glass etch operations.
2. Adjust depth of drill penetration into backer/change backer material.
3. Verify/correct state of cure. (Tg)
4. Reset drilling parameters for material being drilled.
5. Change drills and correct problem causing clogging.
6. Replace chipped drill with new tool.

**Pad (Land) Tearout:**

Pad tearout results when the Land area (usually unsupported) is dislodged from base material.

*Potential Causes:*

1. Excessive heat being generated during drilling process.
2. Dull drill, drills used with the incorrect parameters fail prematurely. This will create excessive heat as described in #1 above.
3. Pad to hole size incorrect.

*Corrective Action:*

1. Change drilling parameters (Speed/Feed & hit count). High RPM and low infeed rate causes excessive heat which under severe conditions will push the inner layer land down on entry and pull up on retract causing unsupported pads to tear away from the "B" stage and "Core" material.

2. If correct diameter drill was used with correct parameters, with no improvement, then this problem can only be corrected by change in design of PWB hole to pad ratio. Or perhaps use of a higher Tg material that will not soften or lift at the normal temperature and stresses developed during drilling.

**Wedge Voids:**

Wedge voids may be identified by cross section as a circumferential attack of the laminate material at the copper interface. Similar to "pink ring" but with a "wedge" of material removed adjacent to the copper layer. Typically there are voids or plating folds in the copper plating at these locations.

*Potential Causes:*

1. Deterioration of process control in the oxide process.
   a. Oxide bath out of balance.
   b. Inadequate rinsing.
   c. Poor handling after oxide.
2. Deterioration of process control in the multilayer lamination process.
   a. Incorrect bake cycles.
   b. Deficient prepreg flow due to age or cycle.
   c. Incorrect resin cure.
3. Deterioration of process control in the drill process.
   a. Drill condition.
   b. Drill feed/speed.
   c. Entry/backer materials.
4. Deterioration of process control in desmear/etch-back process.
   a. Aggressive Plasma cycle.
   b. Aggressive Permanganate cycle.
   c. Glass etch make-up.

*Corrective Action:*

1. Refer to Corrective Action under "Hole Wall Fractures".

**Pink Ring:**

Pink Ring is a delamination of the bond between the 'B' stage material and a copper oxide surface of the inner layer copper. This typically appears surrounding the drilled hole but may appear in areas away from the drilled hole. This happens when acid attacks the oxide through a micro delamination, created at drilling because of the weak bond.

NOTE: Pink ring is not necessarily a drilling related problem, however it is typically and wrongly attributed to drilling.

*Cause:*

1. Deficient bond between the inner layer copper oxide and 'B' stage attributed to:

a. Lack of process control in the oxide process.

b. Control of heat up rate in lamination.

c. Prepreg with lower surface resin (ie 7628).

d. Control of etch-back process.

**Corrective Action**

1. Control the oxide chemistries.
2. Use adequate hot and deionized water rinses in oxide line. (Critical!)
3. Control lamination press cycle within manufactures recommendations.
4. Use prepreg selections (against copper details) which have adequate surface resin. Avoid the use of heavy fabrics such as 7628 against C-stage layers.
5. Adequate rinsing after acid chemistries in copper deposition.

**Burrs:**

Burring is the distortion of copper foil on the outer layer(s) of the PWB. Burrs may be either entry or exit burrs, and may be visible on both sides of the same panel.

*Cause:*

Entry Burrs

1. Lack of entry material.
2. Entry material too thin for the speeds and feeds being used.
3. Debris entrapment between entry material and the PWB.
4. The opening in the drill spindle pressure foot is too large, allowing the vacuum to lift the thin entry material creating an 'Oil can' effect.
5. Soft entry material.

**Exit Burrs**

1. Debris entrapment between panels or between the bottom of the panel and the backer material.
2. Backer material too soft for material being drilled.
3. Debris clogging the flute of the drill.

*Corrective Action:*

Entry Burrs

1. Use entry material on all drill sizes drilled with a chipload in excess of .0015" (For drills used with less than a .0015" chip load, entry material protects the surface of the PWB from damage and to aids the drill for a more accurate penetration of the board material).
2. Replace entry material with a thicker or more rigid material.
3. Clean the surface of the PWB and the entry material of all debris and dust prior to drilling.
4. Replace entry material with a more rigid material or reduce the amount of vacuum being used.
5. Replace the entry with a harder material.
6. Use smaller diameter or variable diameter pressure foot.

Exit Burrs

1. Clean the backer, the drill table and both sides of each panel prior to installing on drill table. (All material should be wiped off with a tack cloth before placing on the drill table).
2. Replace backer material with a harder material.
3. Correct flute clogging, (resin cure, entry material, backer material, etc.).

**Misregistration**

Misregistration is the failure of alignment of one or more of the inner layers to the other inner layers or the drilled hole. While drilling adjustments may help mitigate the effect, this is often not a drilling issue per-se unless the drill tape or photo tooling have problems. (See below)

*Potential Cause:*

Layer To Layer:

1. Photo tool incorrectly used or punched.
2. Material movement during etch or lamination.
3. Misregistration in dryfilm.

Layers To Hole

1. Location of tooling holes on drill table off in relation to panel tooling holes.

2. Drill machine positions incorrectly (runs short or long).

3. Drill spindle has excessively high run out.

4. Drill bit deflects on entry or through drill stack.

*Corrective Action:*

Layer To Layer:

1. Re-tool photo tools - check for proper use.

2. Size artwork to compensate for material movement on core material.

Layers To Hole

1. Make new set-up on drilling machine.

2. Service drill machine to move to correct distances.

3. Change collets in drill spindles or change drill spindle.

4. Change entry material, speeds and feeds, or drill bit design.

5. Adjust size drill program.

NOTE: Correct layer alignment to each other, then correct alignment of drilled hole to the layers.



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