Peel Strength of Deposited Adhesiveless FCCL, Or,
Why Don't They Ever Say, "It Sticks Too Good?"

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EXECUTIVE SUMMARY

The peel test will be reviewed, with special attention given to deposited adhesiveless copperclad laminates. A basic familiarity with the IPC test method will be assumed. The brief amount of time allotted permits focus on two general topics.

First, data will be presented to illustrate the influence of a number of variables on peel strength values, such as conductor thickness, conductor width, and copper treatment, as well as more subtle things such as surface finish and even simple choice of test method.

Second, a detailed comparison of adhesion performance between deposited materials and their cast and laminated cousins will be provided as well.

Peel Behavior of Deposited Adhesiveless fccls, or Why Don’t They Ever Say, “It Sticks Too Good?”

Brent Sweitzer

Sheldahl Technical Materials

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Agenda

- Methods of fabrication
- Advantages of “deposited” product
- Factors affected peel strength
- Comparison of deposited product to cast or laminated versions

Adhesiveless **F**lexible **C**opper**C**lad **L**aminates:

Methods of fabrication

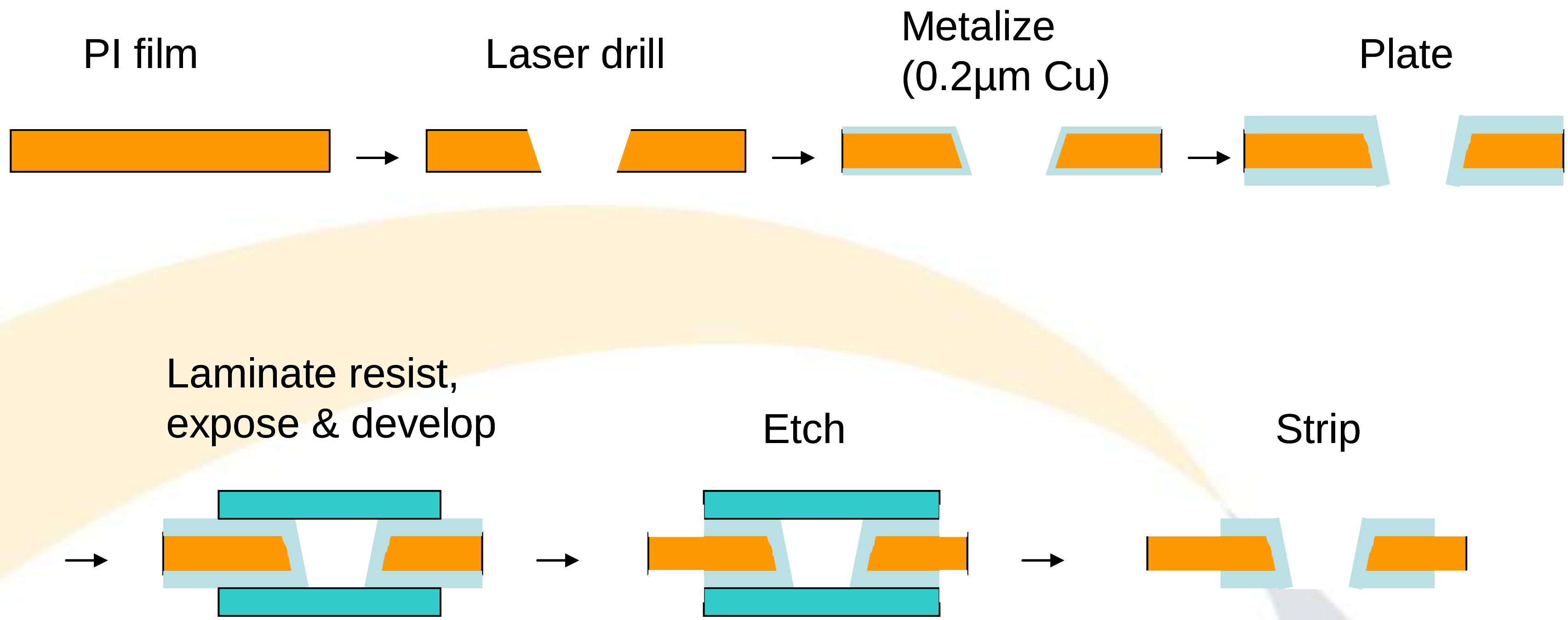
- Casting
  - Coat and dry resin on copper foil. Cure.
- Laminating
  - Coat & dry thermoplastic polyimide resin on PI base film. Laminate copper foil.
- **Vacuum deposition**
  - **Deposit tiecoat & copper on PI film. Electroplate more copper.**

Advantages of deposited FCCLs

- Smooth interfaces
  - Good transmission characteristics at high frequency
  - Precise etching of fine features

- Economical thin copper (2-8µm)
  - Excellent flexibility
  - Expanded processing options

Pre-fabricated 1mil PTHs



So, why a paper on the Peel test?

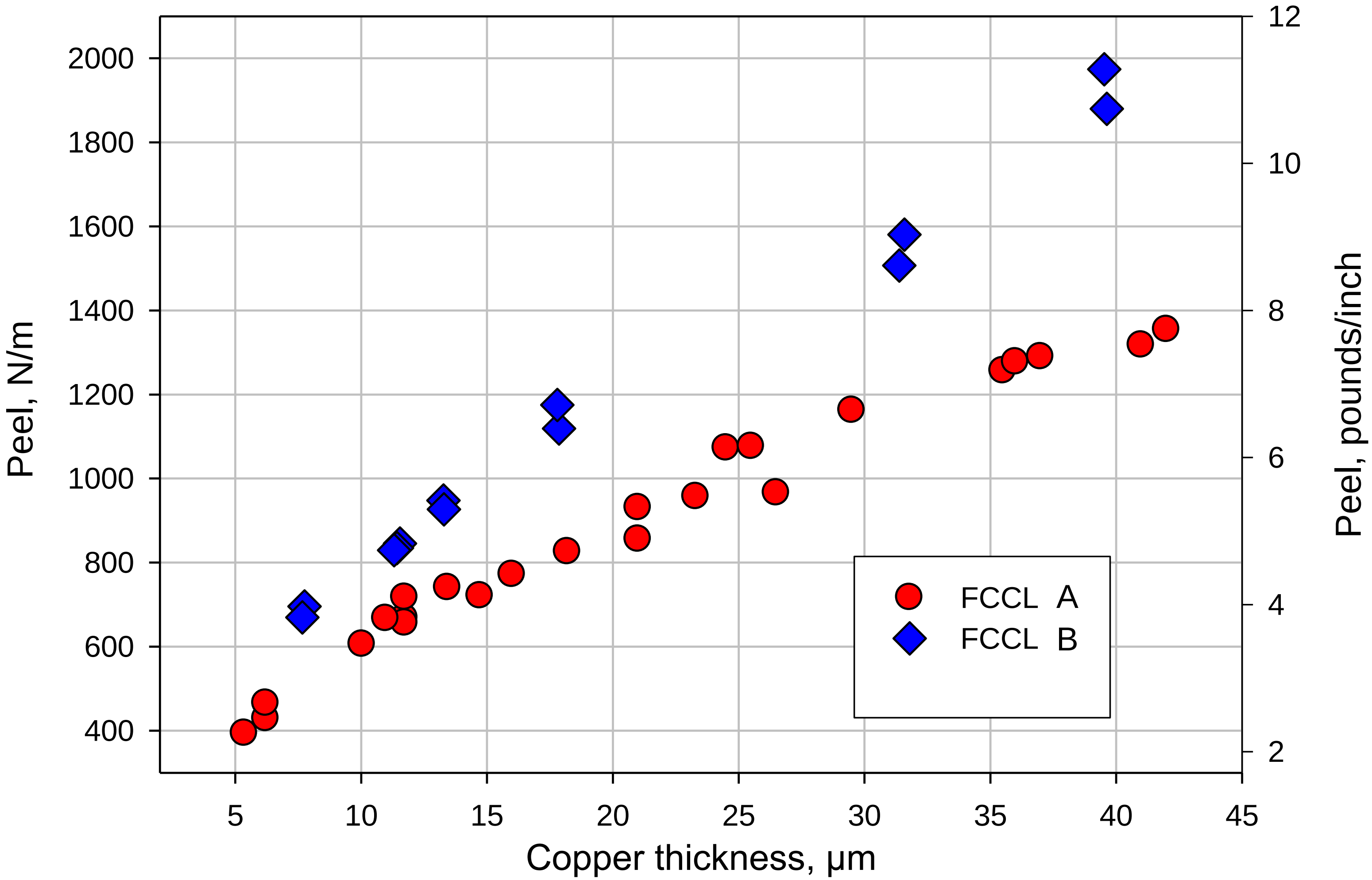
The industry is very familiar with foil-based materials

- The influence of treatment profile, bulk resistivity, and thickness on peel strength are well-understood for foil-based FCCL.
- An understanding of these factors will help us to draw good conclusions when it comes to deposited adhesiveless materials.

Factors affecting peel strength

- Copper thickness.
  - 80% of the force goes into bending the copper.

Dependence of 90°peel on copper thickness for two different deposited FCCLs

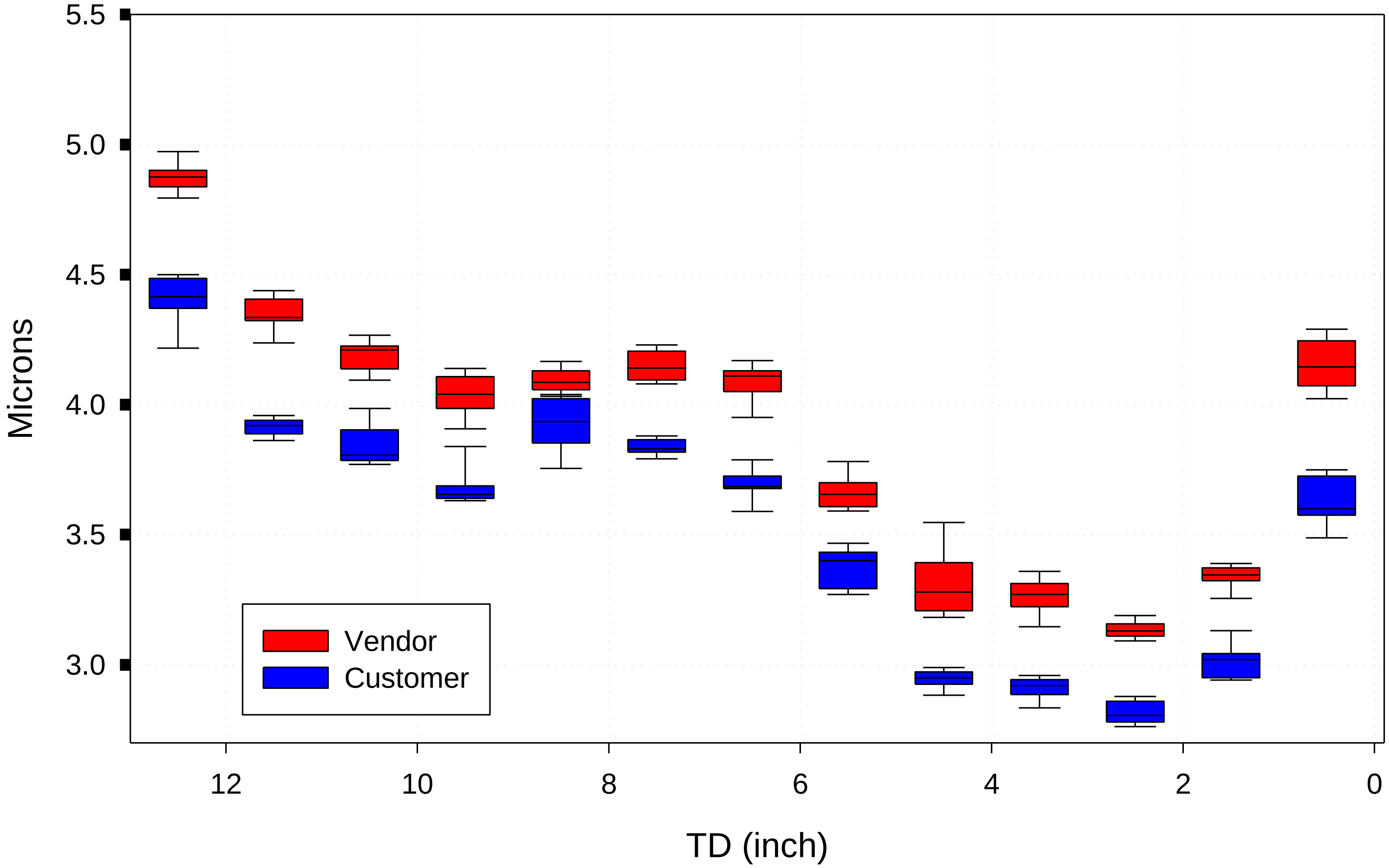


1/8” etched traces

Accurate thickness measurement is important

- Thickness generally is inferred from resistance measurement.
- The bulk resistivity of brightened fine-grained copper plating differs from ED foil.
- As well, the resistivity will change by almost 20% as the deposit relieves stress.

Vendor & Customer measurements using different calibration standards



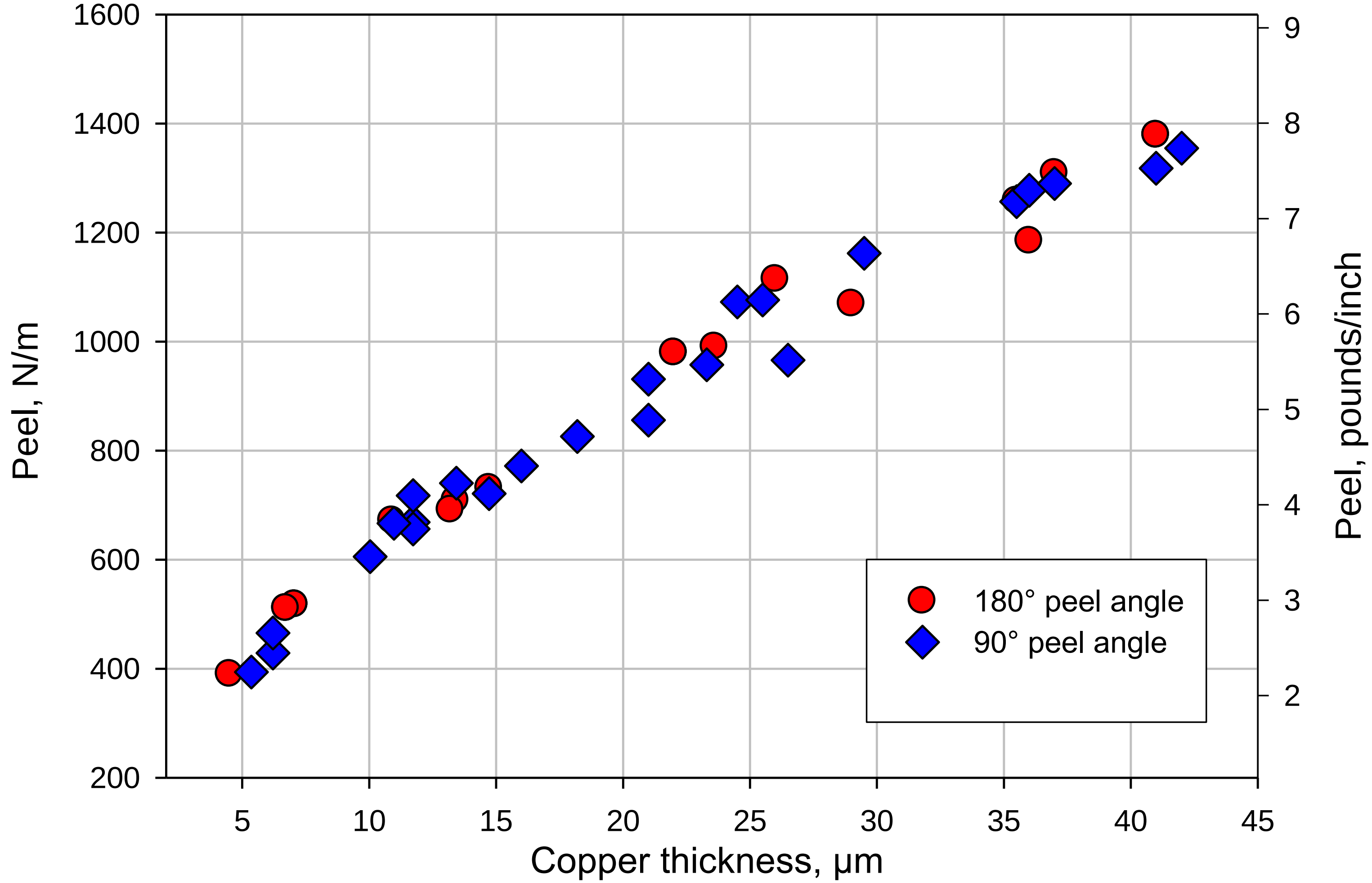
For accurate copper thickness by resistance measurement…

- Use standards built on the same material you intend to test.
- Have a care for the size of the feature you are measuring.
- Standards should bracket the range of measurement.
- Be sure the copper has “stress-relieved” before measuring.

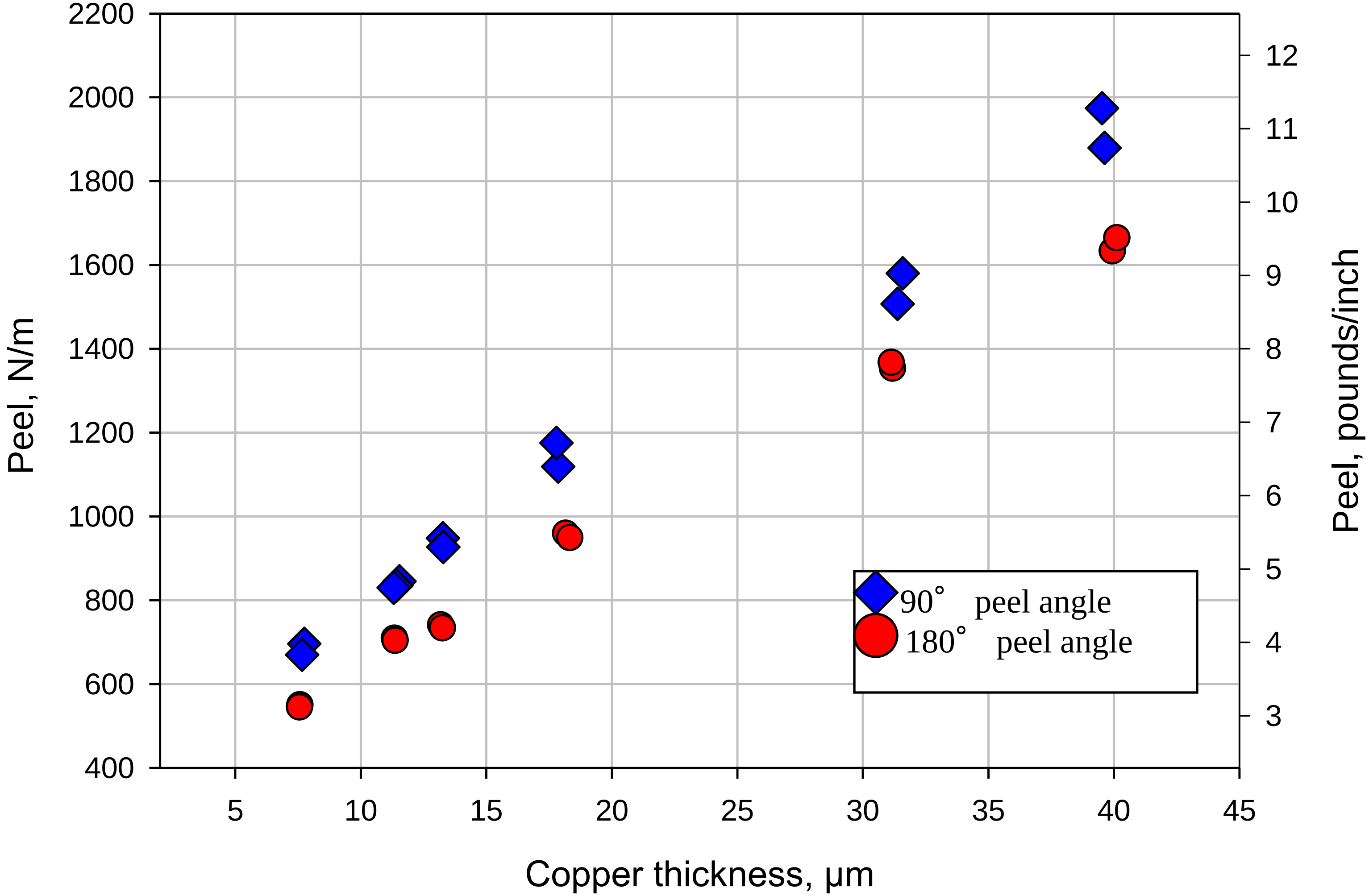
Factors affecting peel strength

- Copper thickness.
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic peel strength

Peel of 3mm etched conductor vs. copper thickness in doubleside format for deposited adhesiveless FCCL 'A'



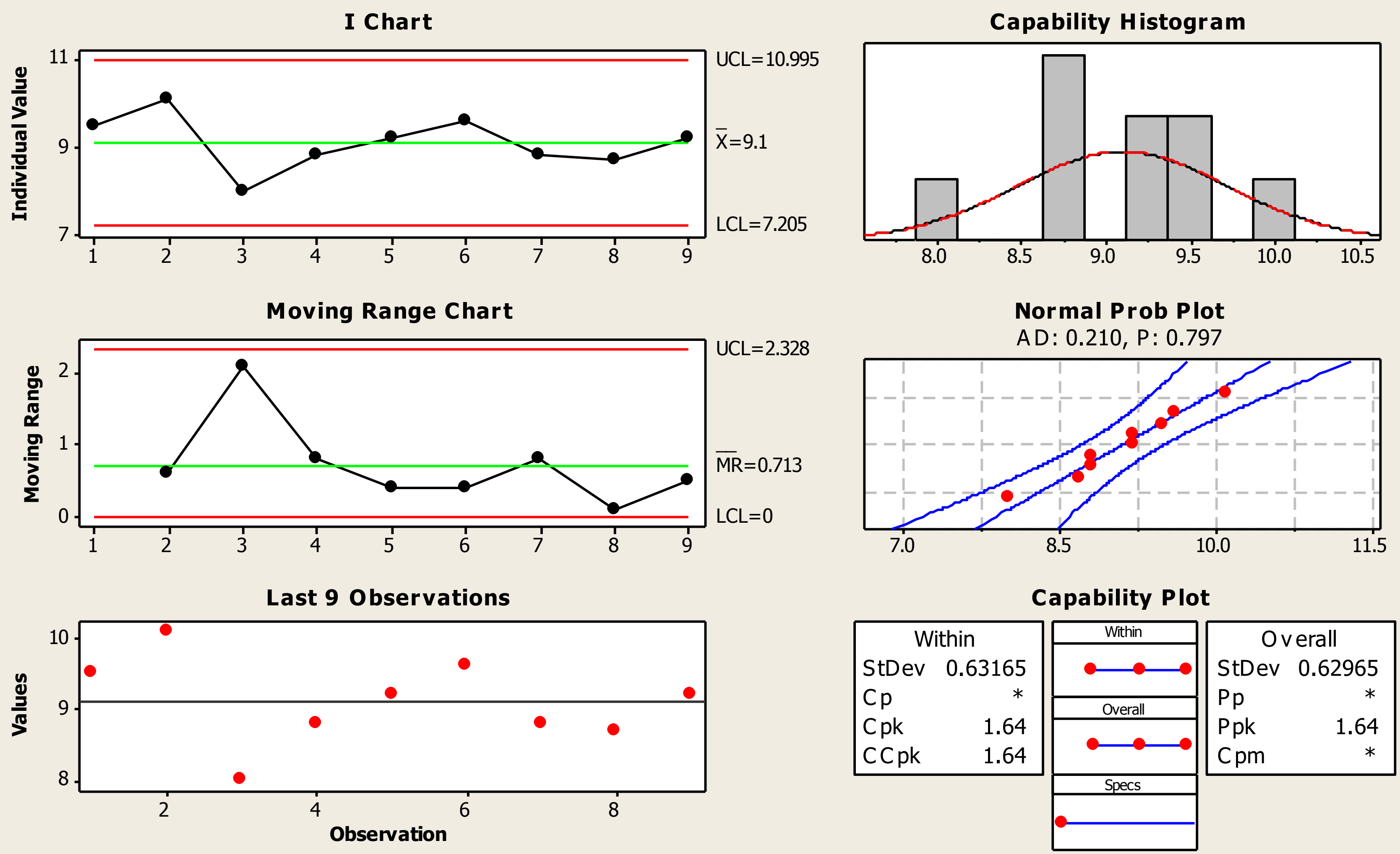
Peel of 3mm etched conductor vs. copper thickness in double-sided format for deposited adhesiveless FCCL 'B'



Factors affecting peel strength

- Copper thickness
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic peel strength
- Film thickness
  - For double-sided coupons, not much…

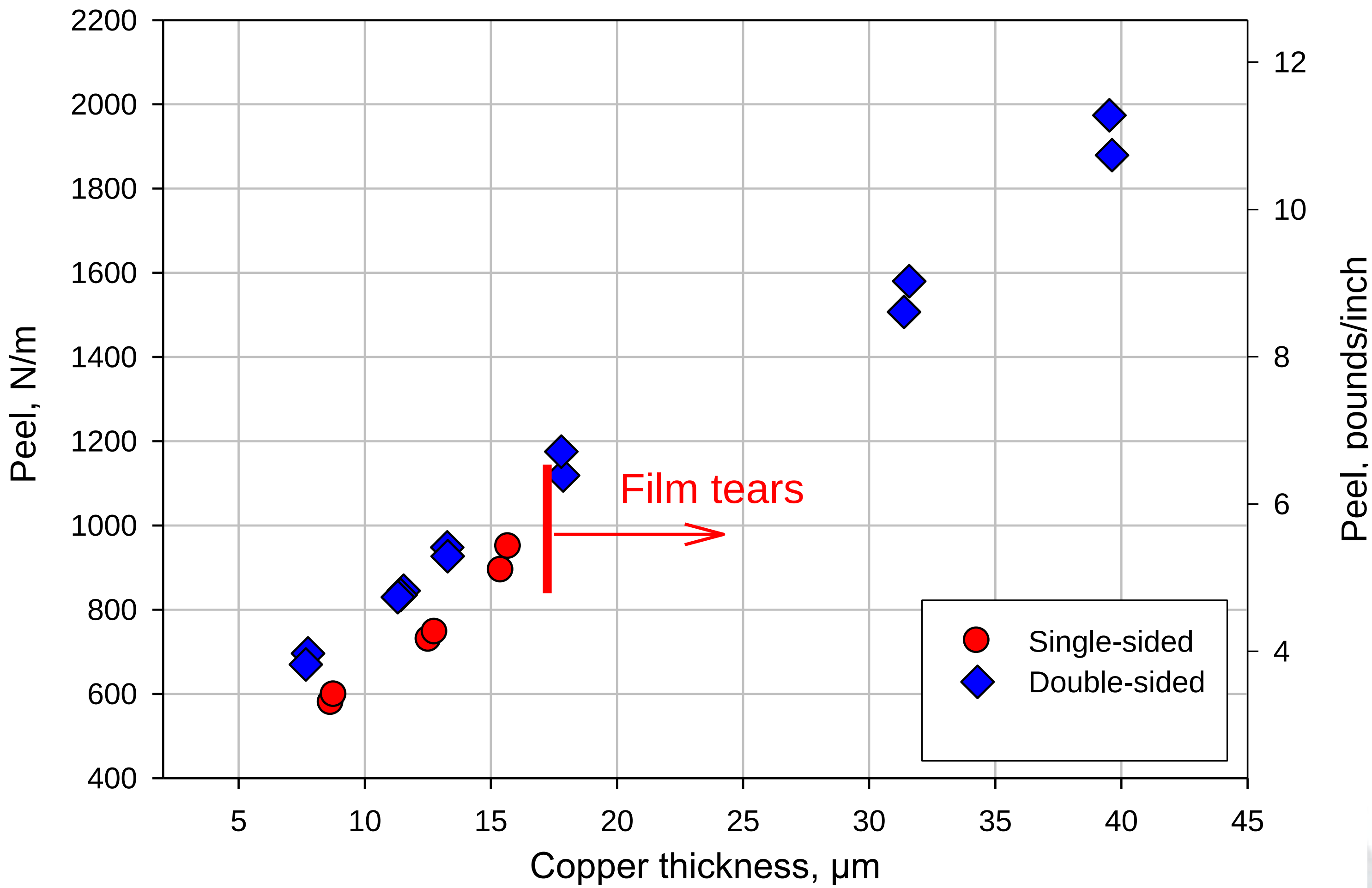
As received peel for 12.5µm PI x 35µm copper



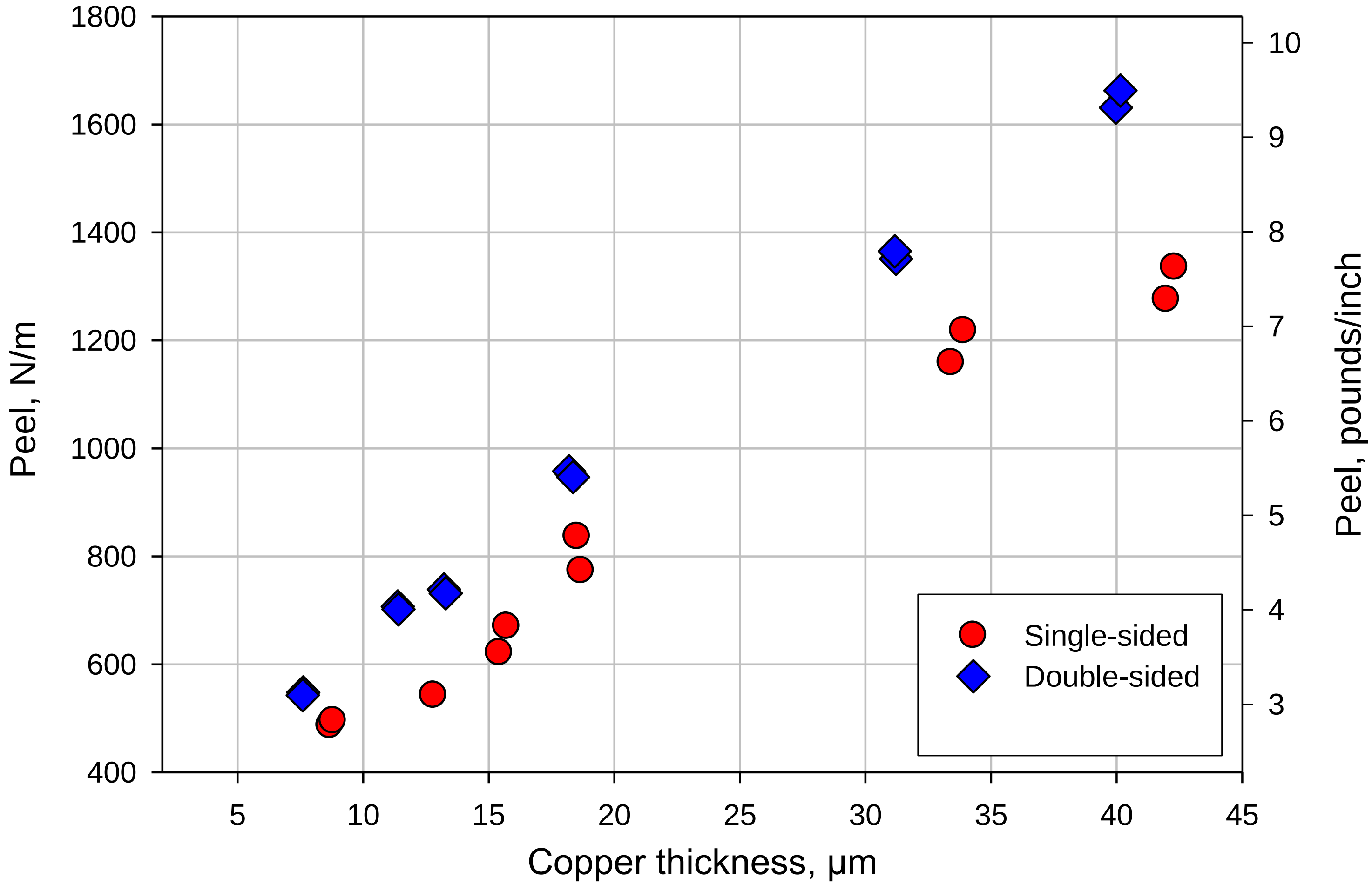
Factors affecting peel strength

- Copper thickness
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic peel strength
- Film thickness
  - For double-sided coupons, not much…
- Backside reinforcement
  - Depends on the peel angle
  - Required for thicker copper at 90˚

Effect of backside cladding on peel strength at 90° peel angle of 3mm etched trace for FCCL 'B'



Effect of backside cladding on peel strength at 180° peel angle



Factors affecting peel strength

- Copper thickness
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic adhesion
- Film thickness
  - For double-sided coupons, not much…
- Backside reinforcement
  - Depends on the peel angle and intrinsic adhesion
  - Required for thicker copper at 90˚
- Die cut vs. etched
  - Beware of failure mode change
  - Values may be higher or lower

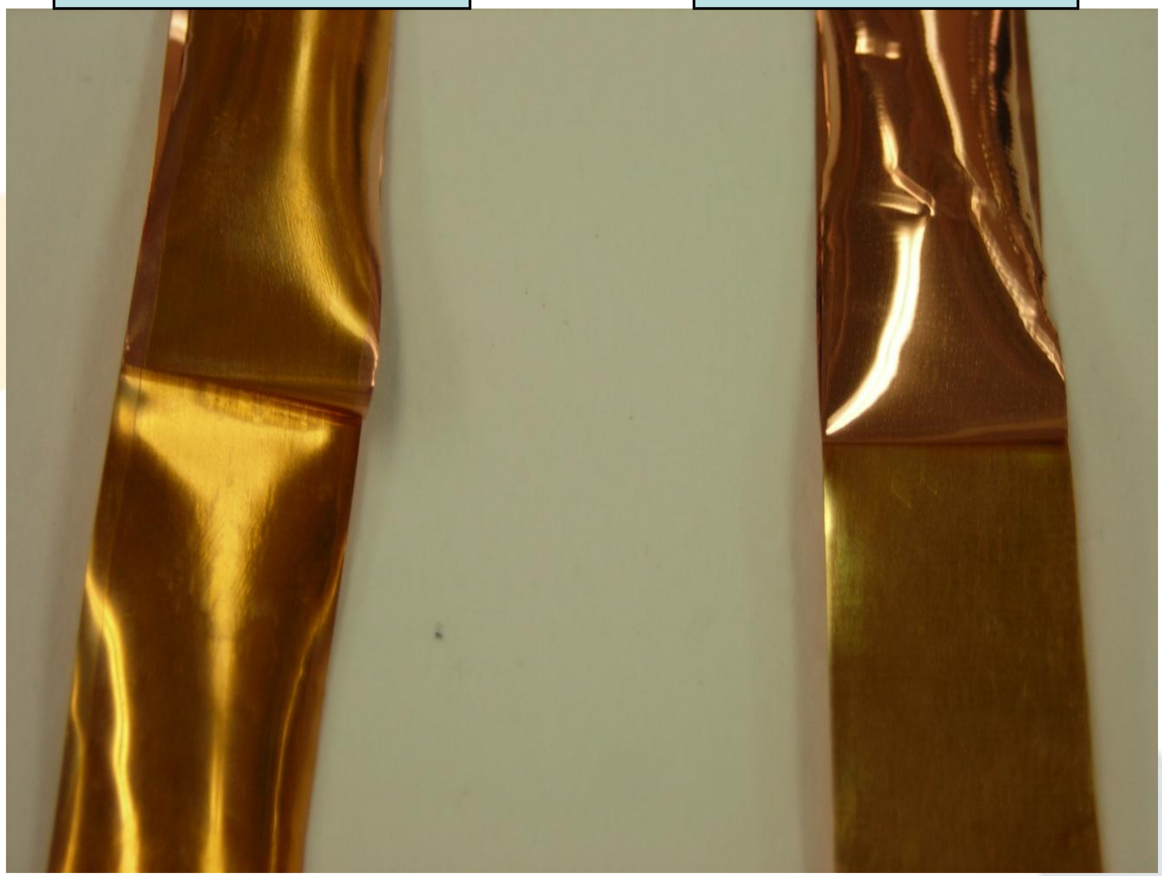
Split film is rare with etched conductors

Split film failure
(deep within film)

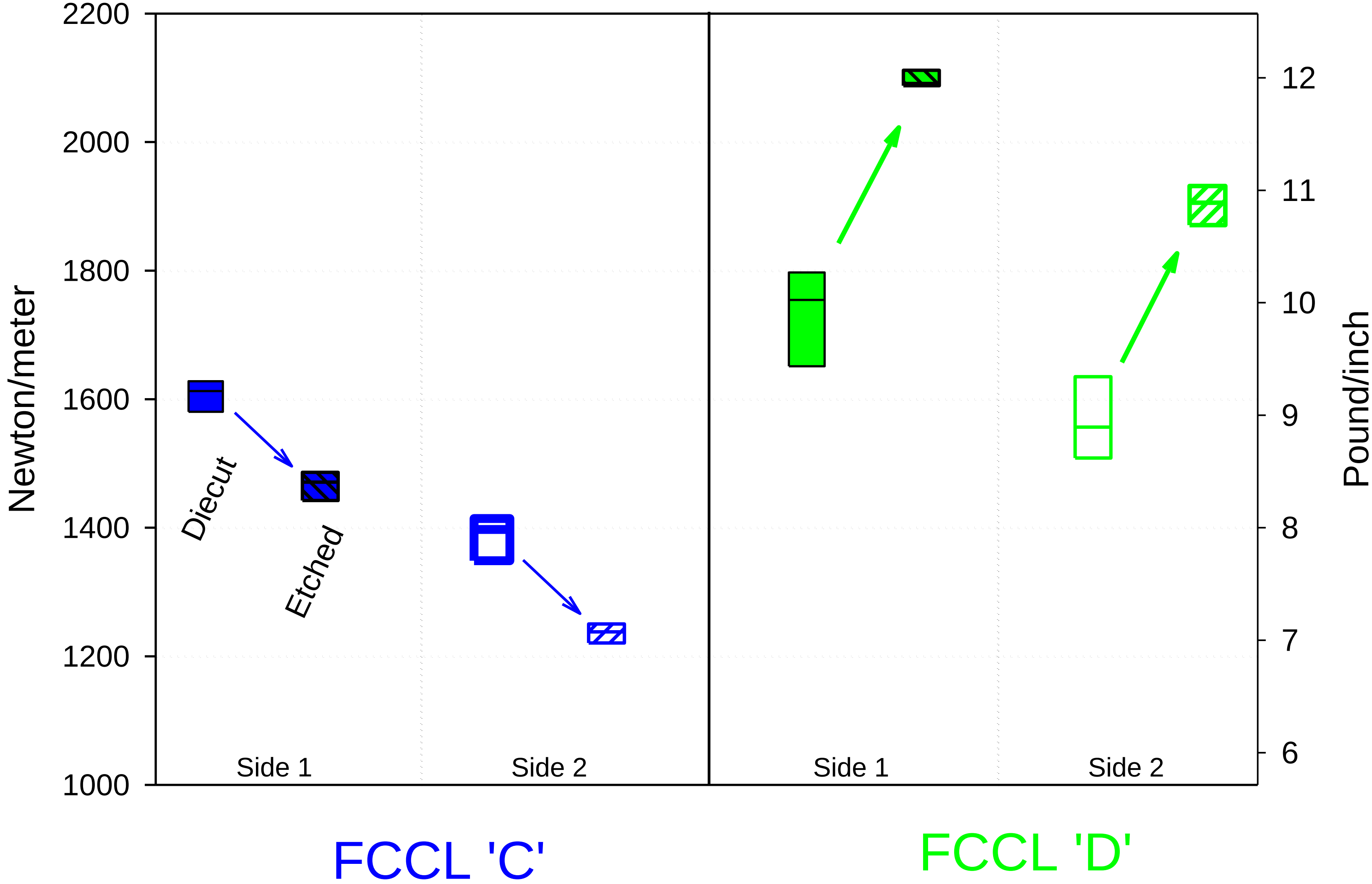
Cohesive failure
(near interface)

Peeled die-cut conductor

PI base



Diecut vs. Etched peels - 35µm Cu

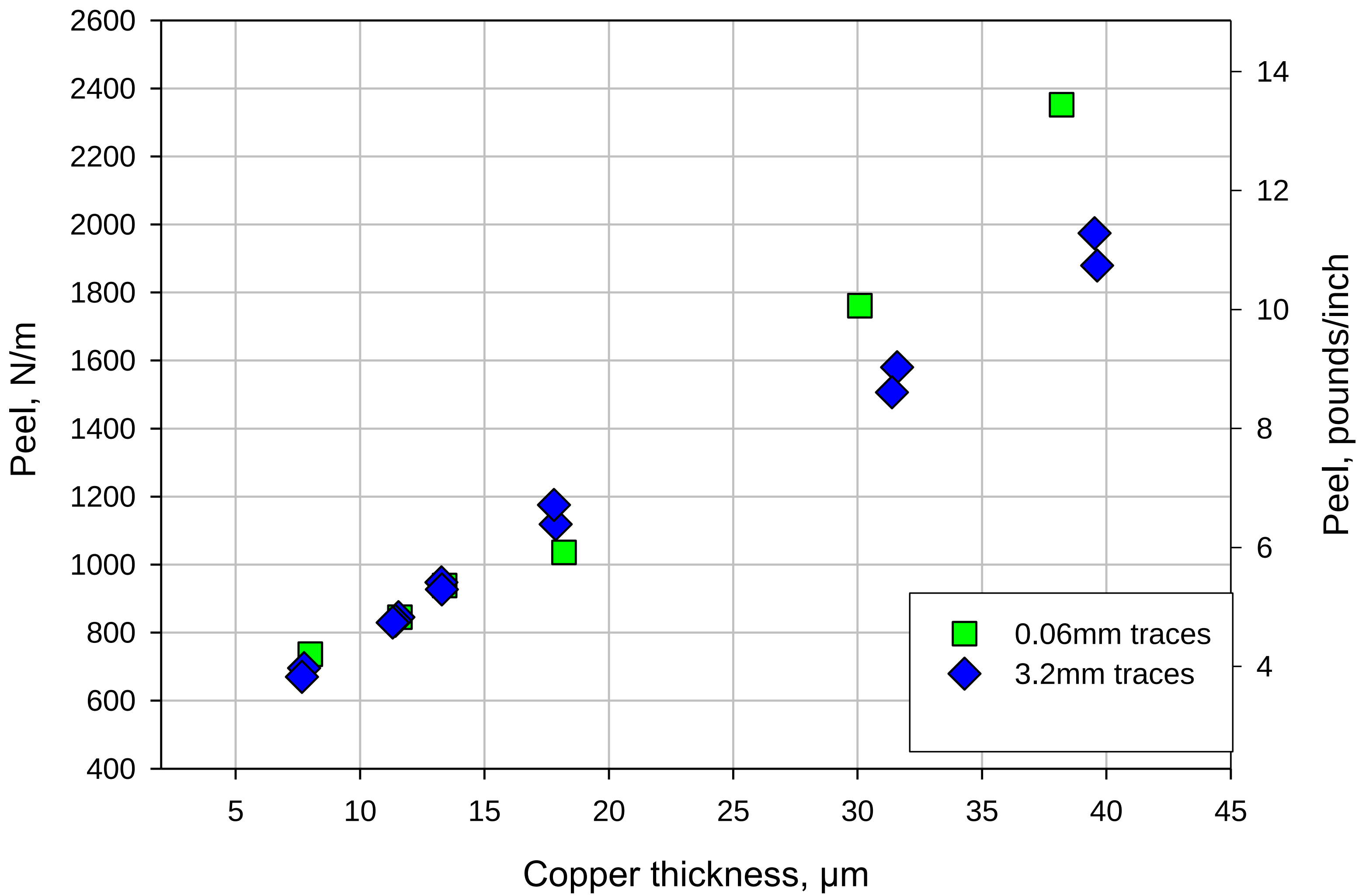


Cross-hatched symbols represent etched conductors

Factors affecting peel strength

- Copper thickness
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic adhesion
- Film thickness
  - For double-sided coupons, not much…
- Backside reinforcement
  - Depends on the peel angle and intrinsic adhesion
  - Required for thicker copper at 90˚
- Die-cut vs. etched
  - Could go up or down
  - Beware of failure mode change
- **Etched conductor width**
  - **Not very significant…**

Effect of trace width on peel strength at 90° peel angle



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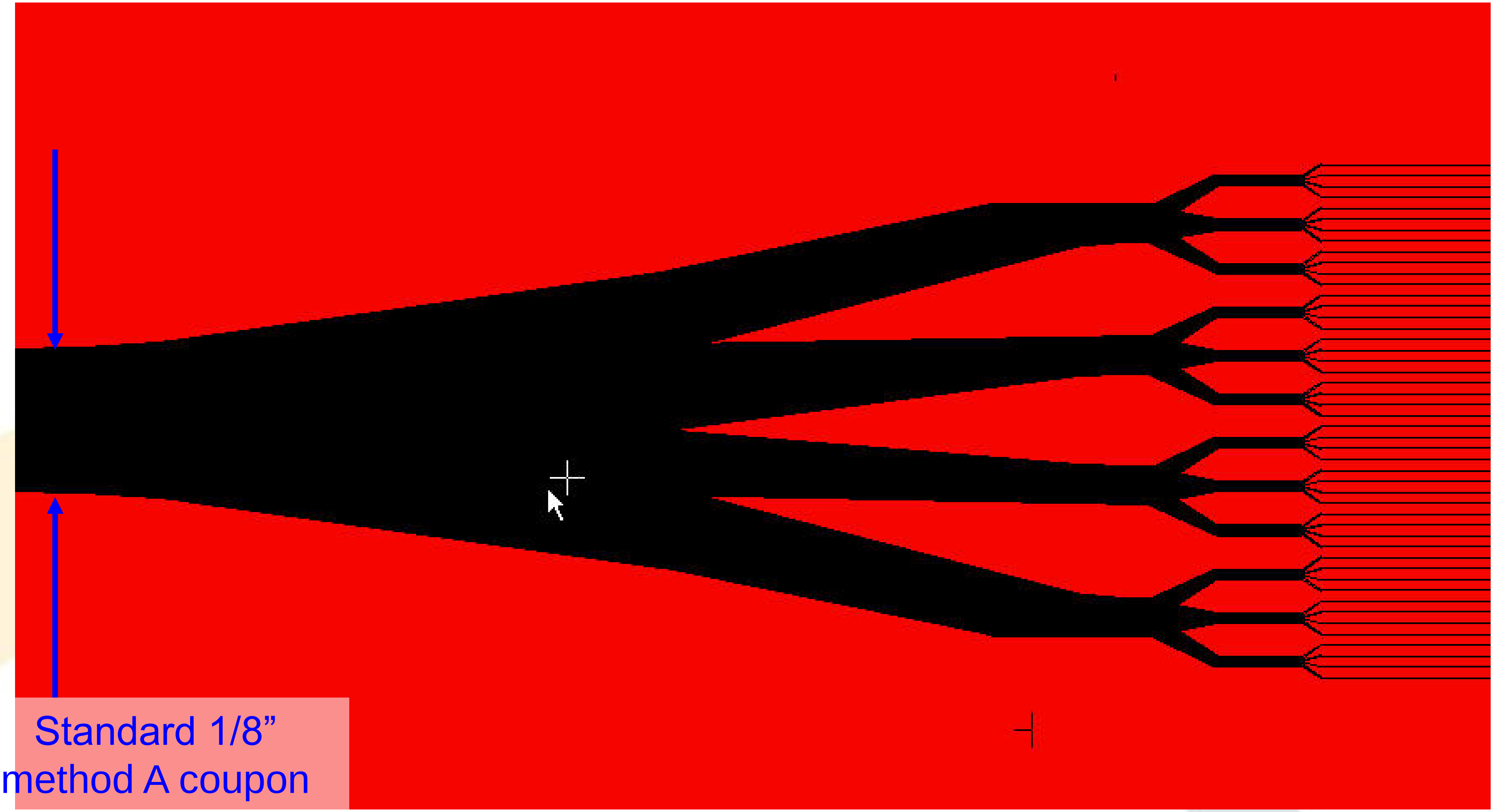
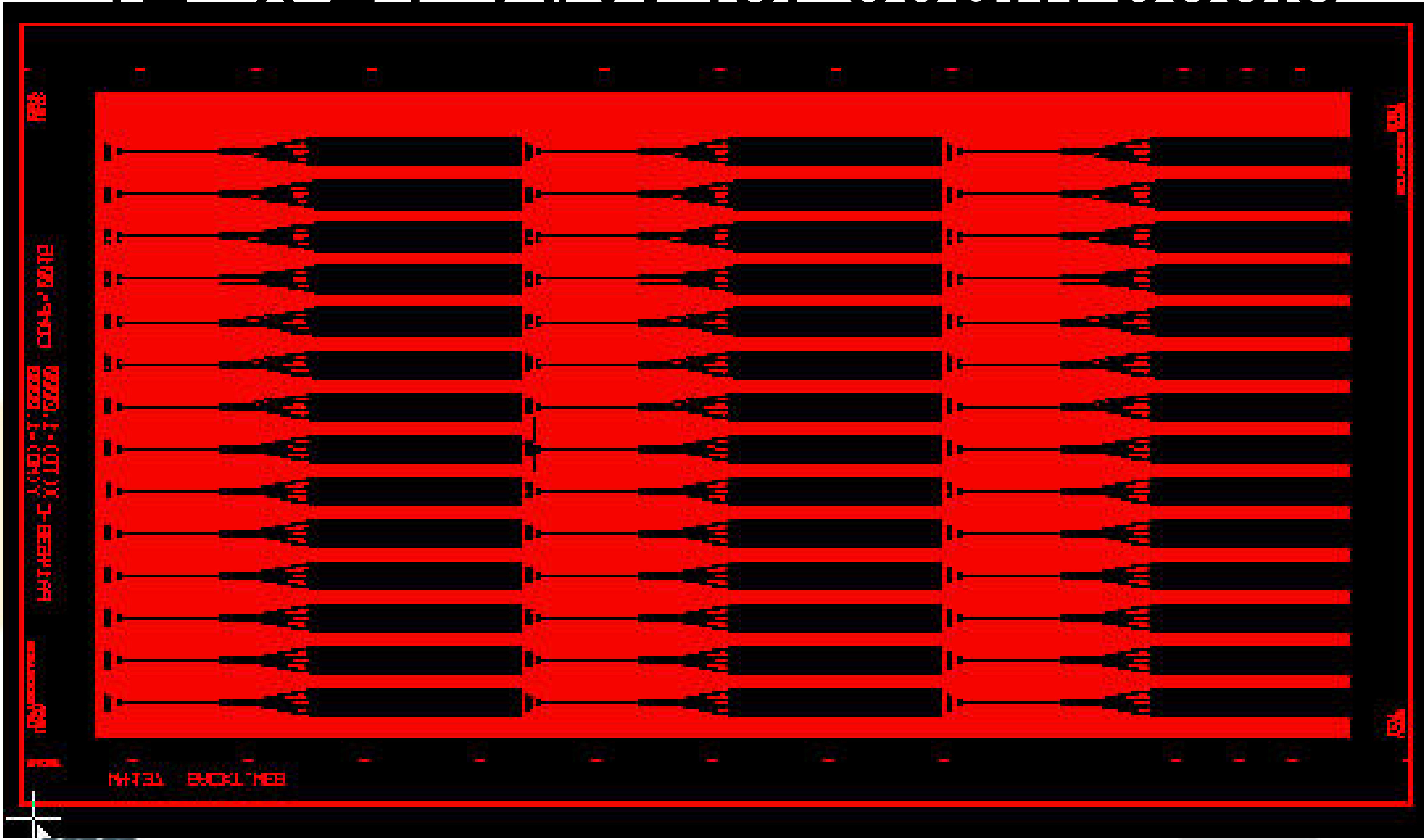
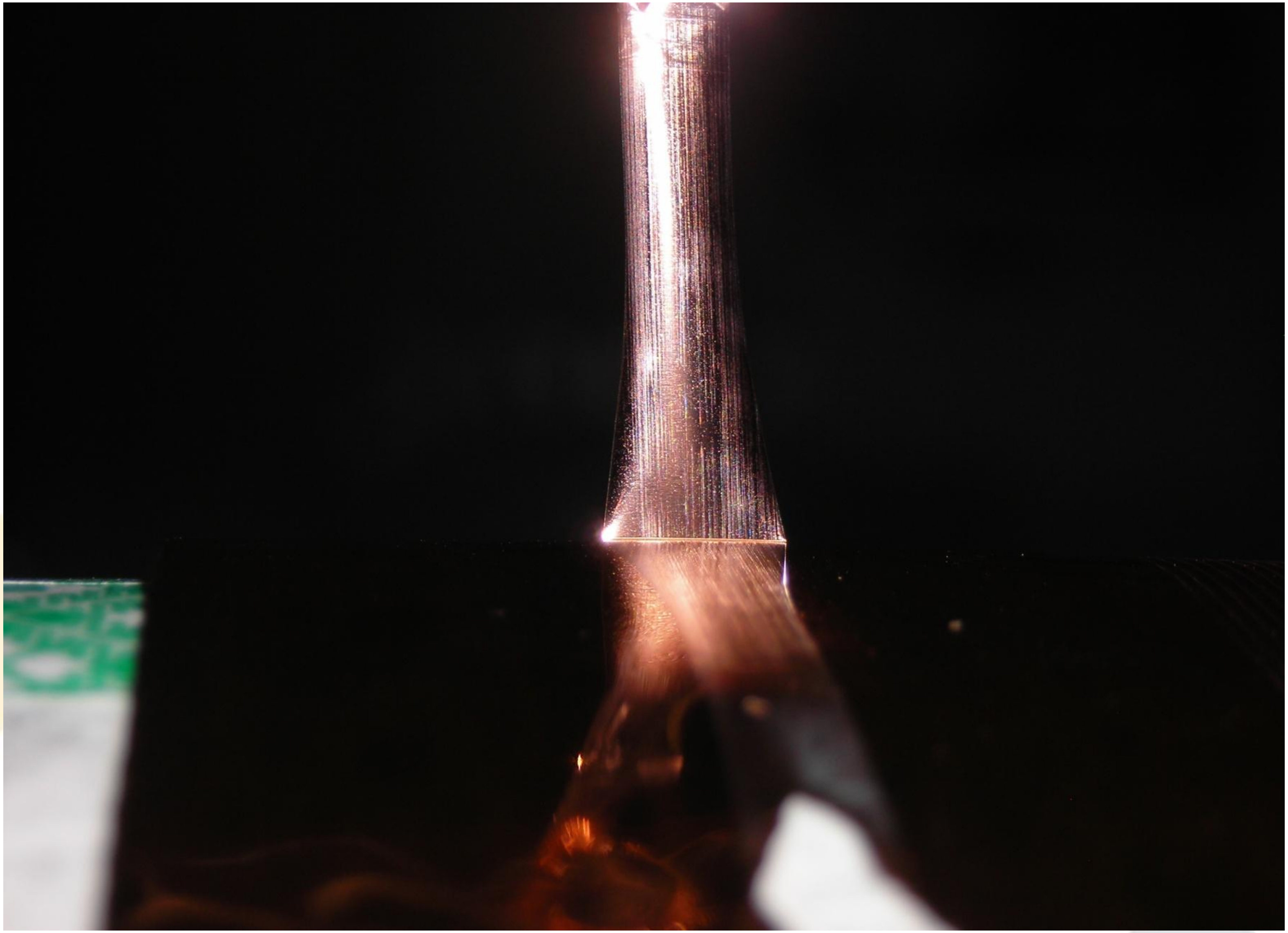
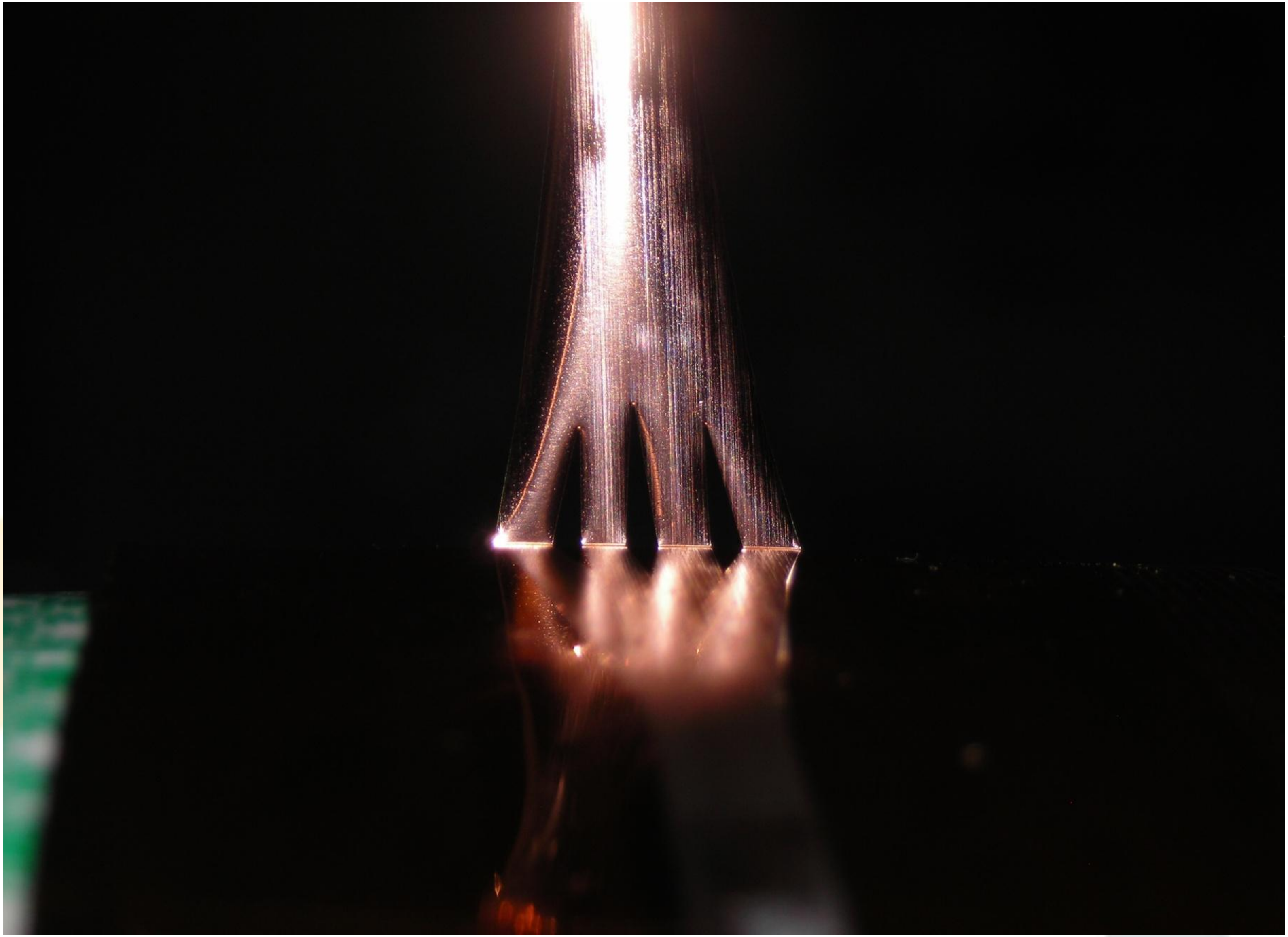
75µm A/W

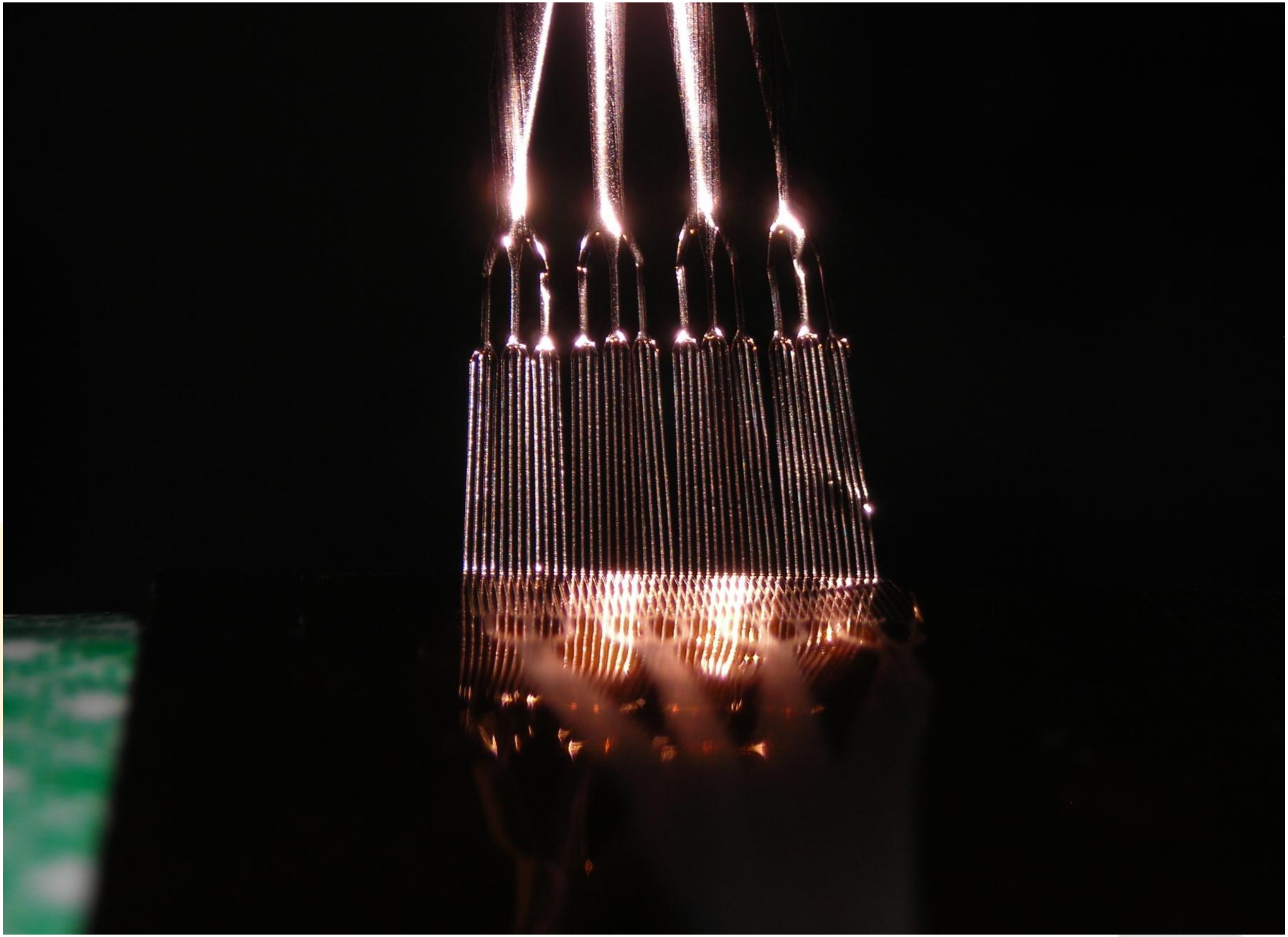


12” x 24” A/W for 60um peels









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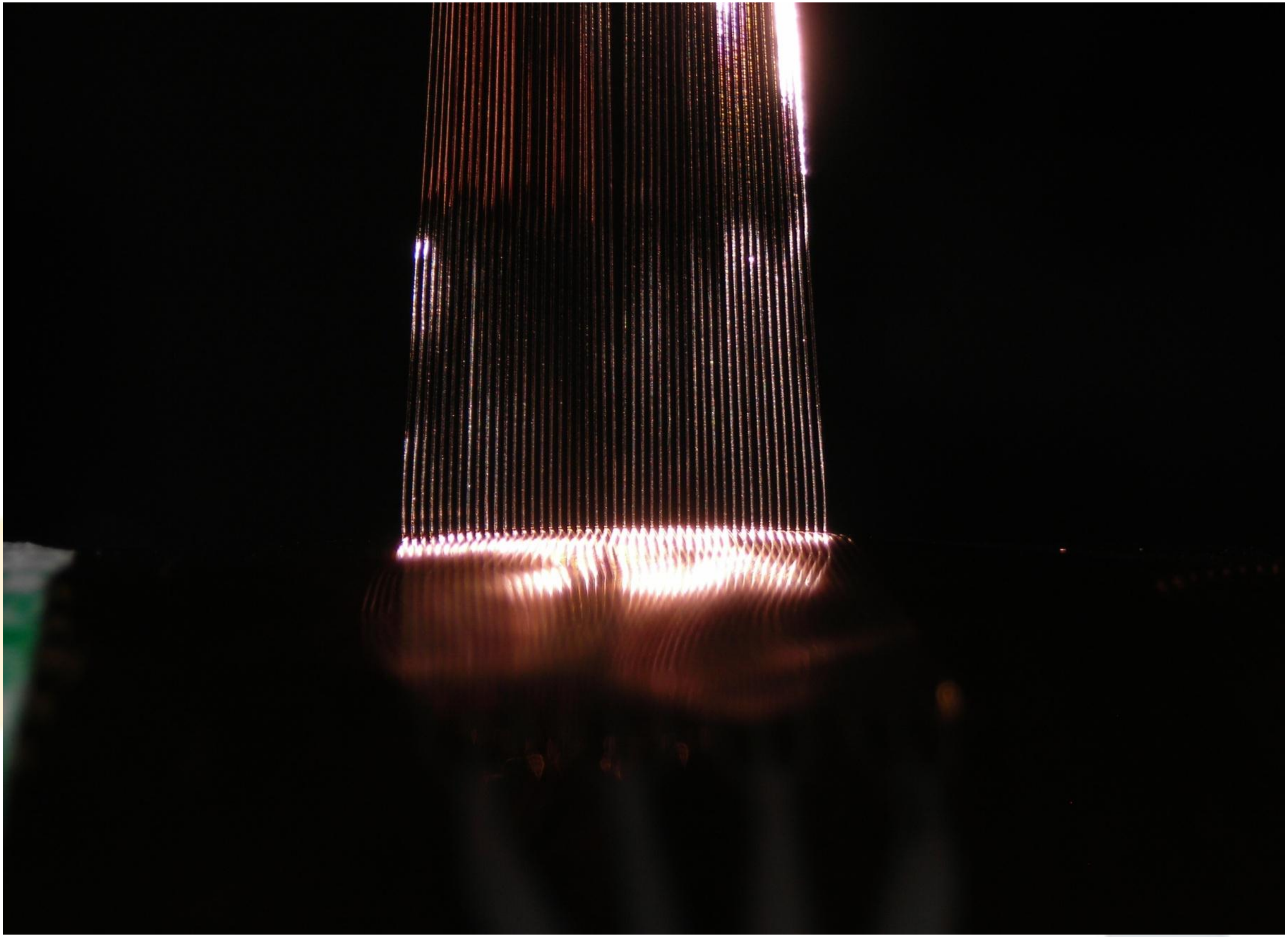

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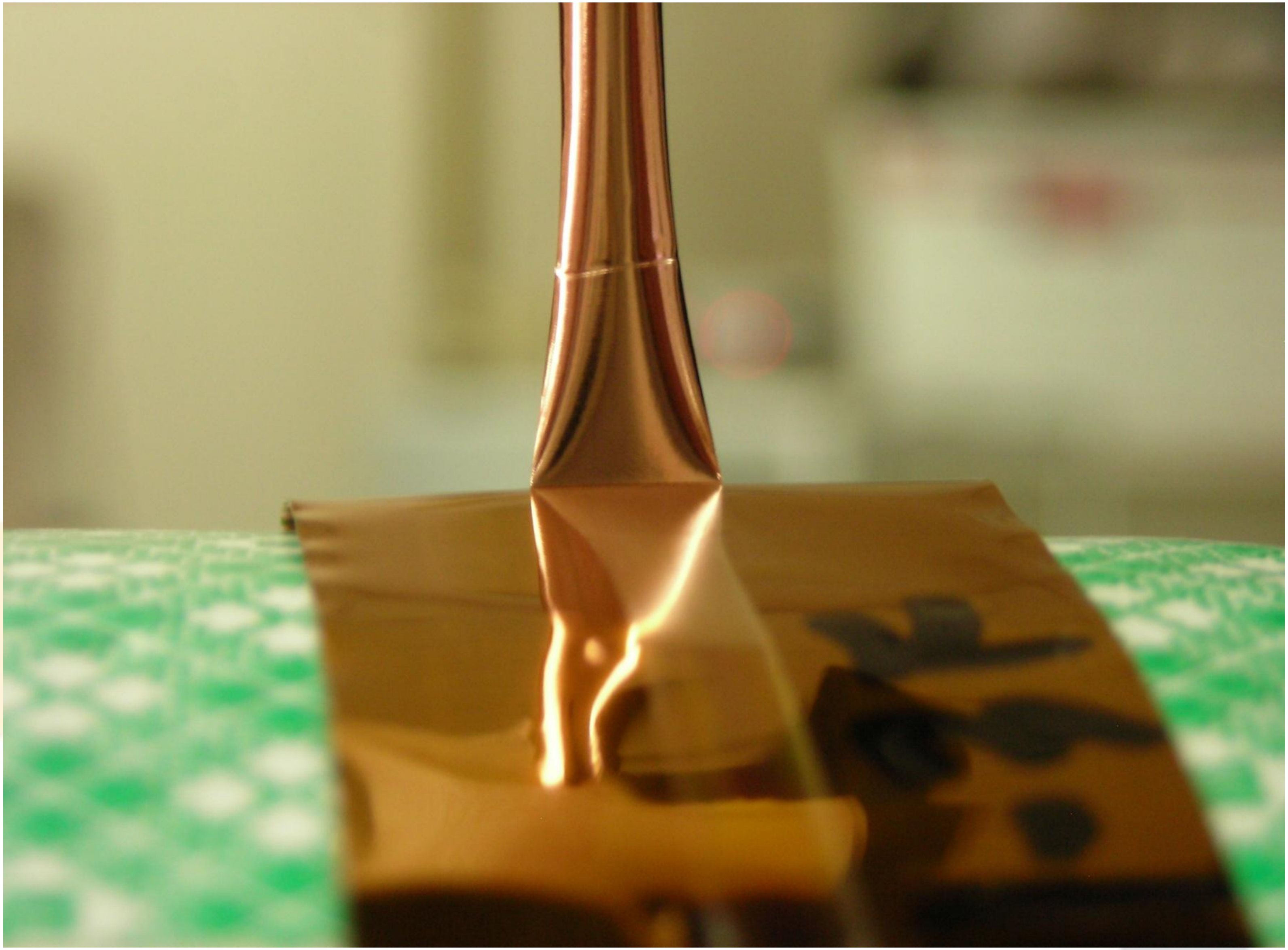
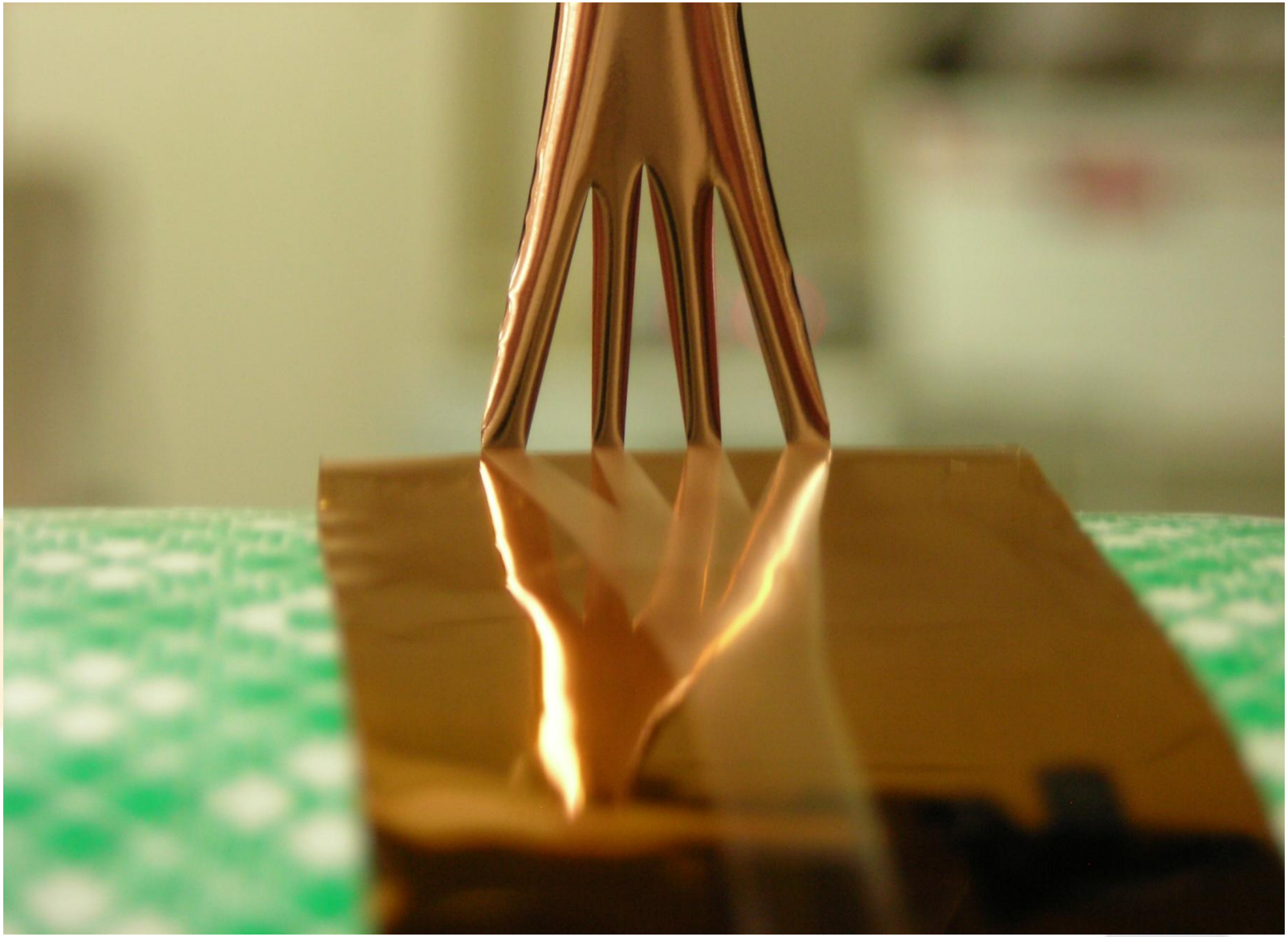
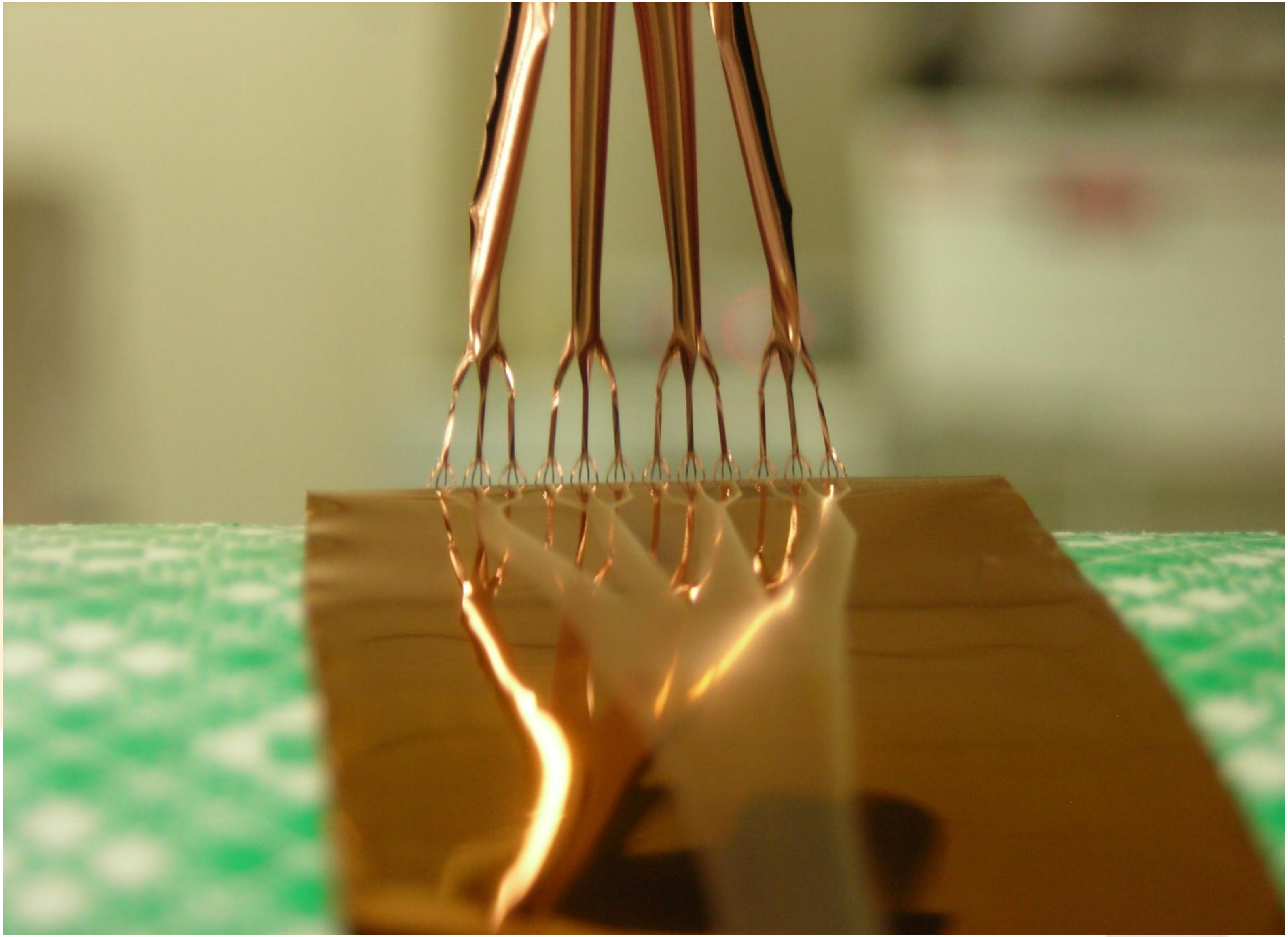
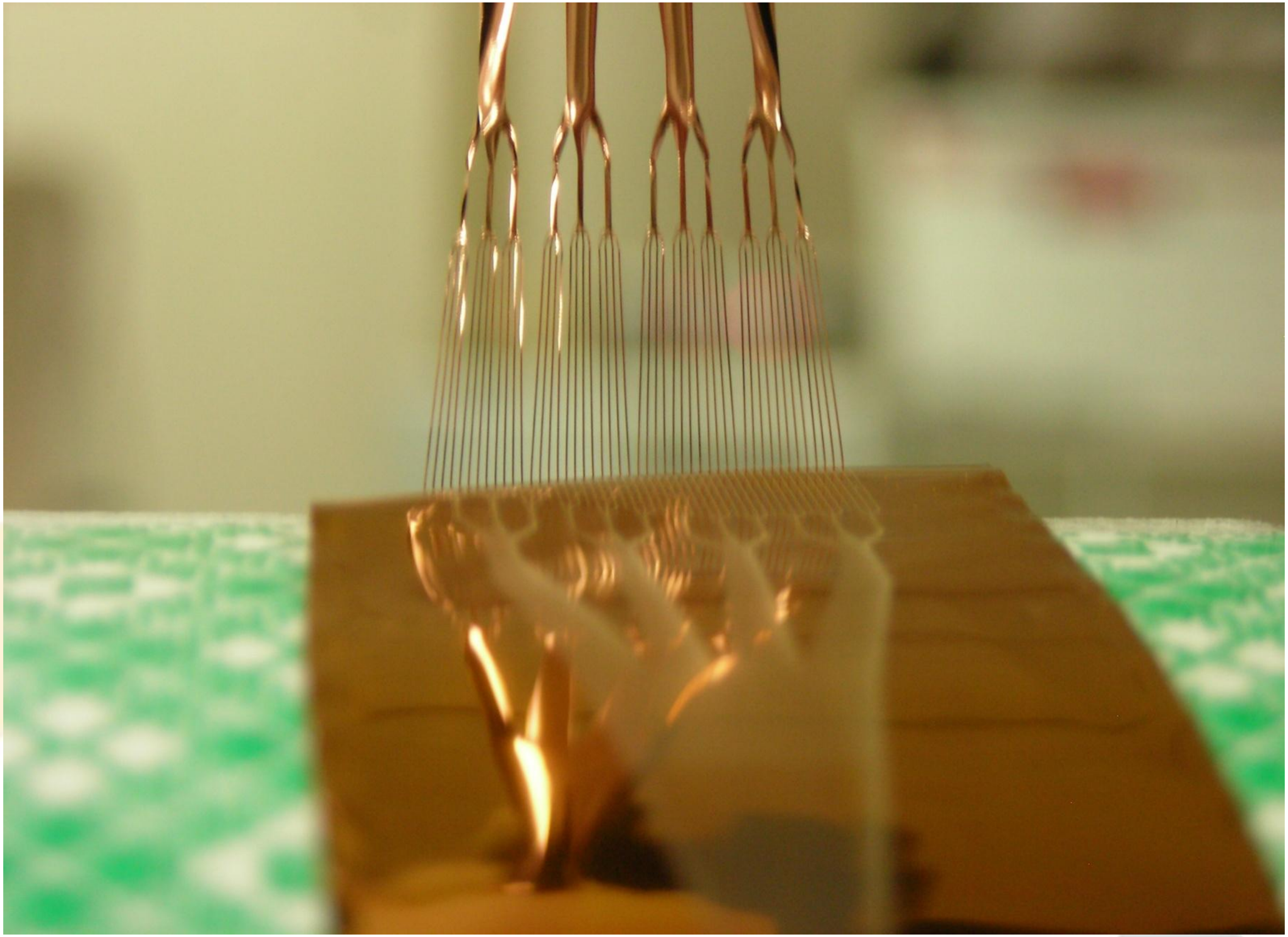
CONFERENCE & EXHIBITION









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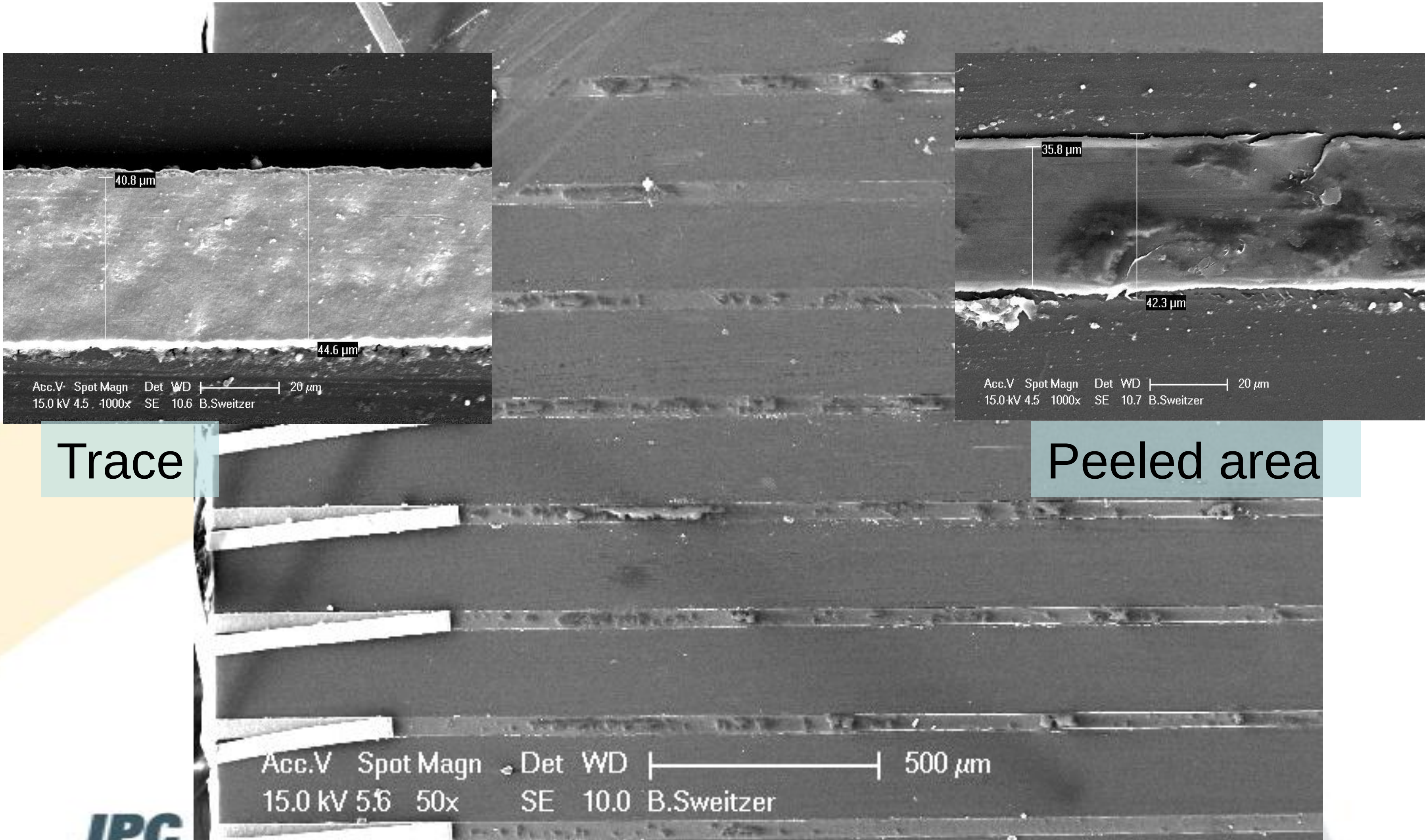
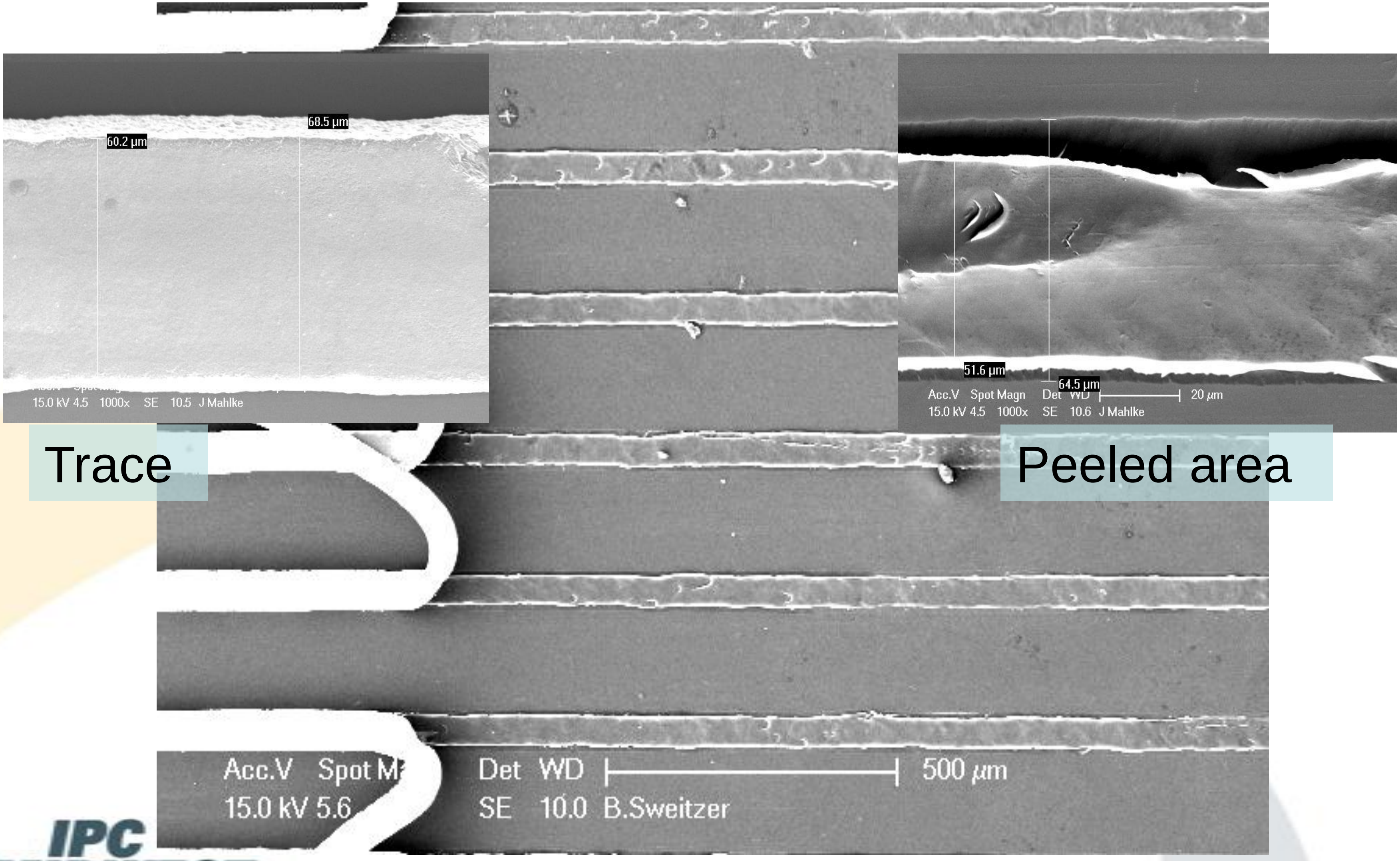
8µm thick 45µm traces

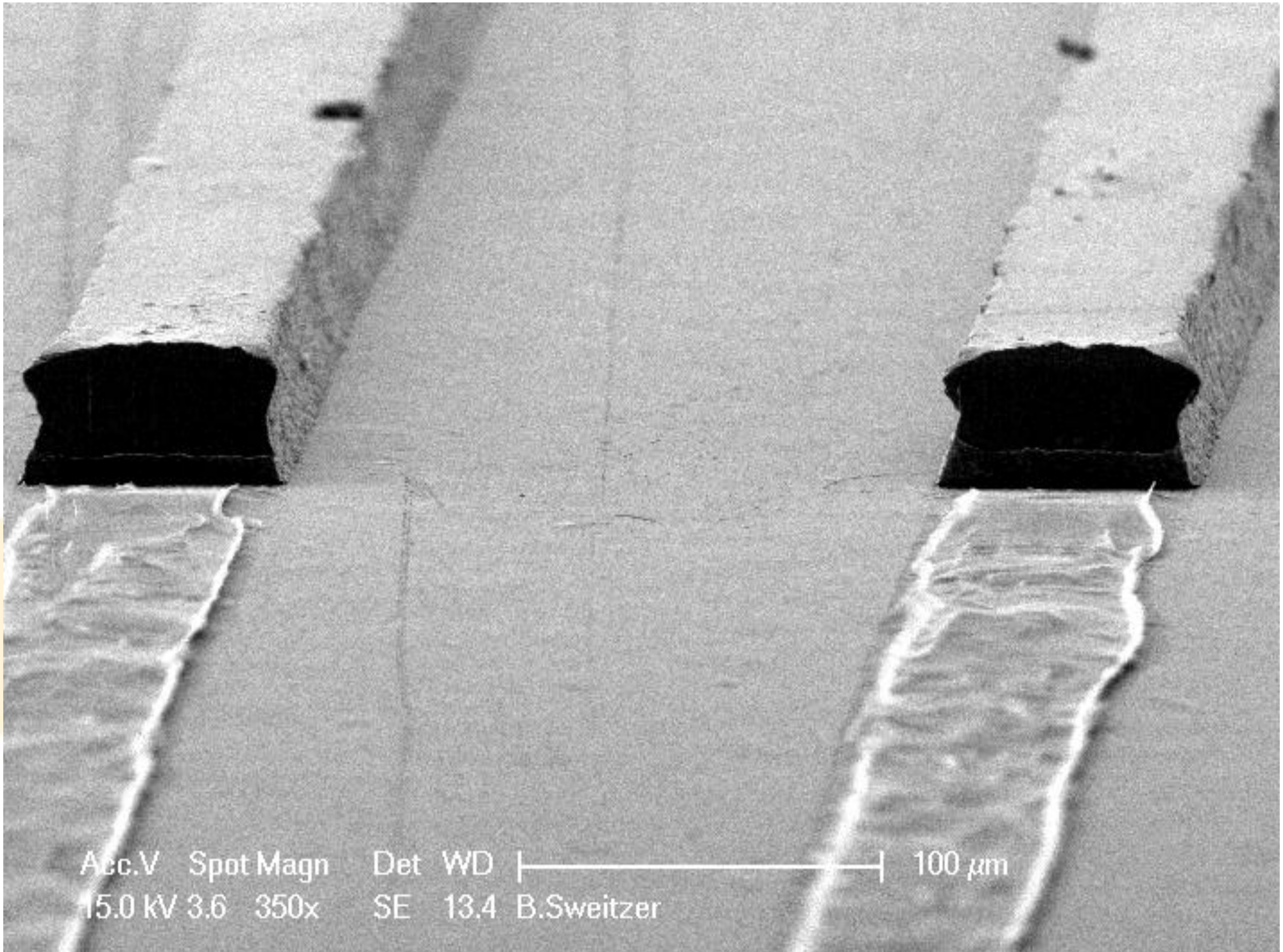


38µm thick 70µm traces

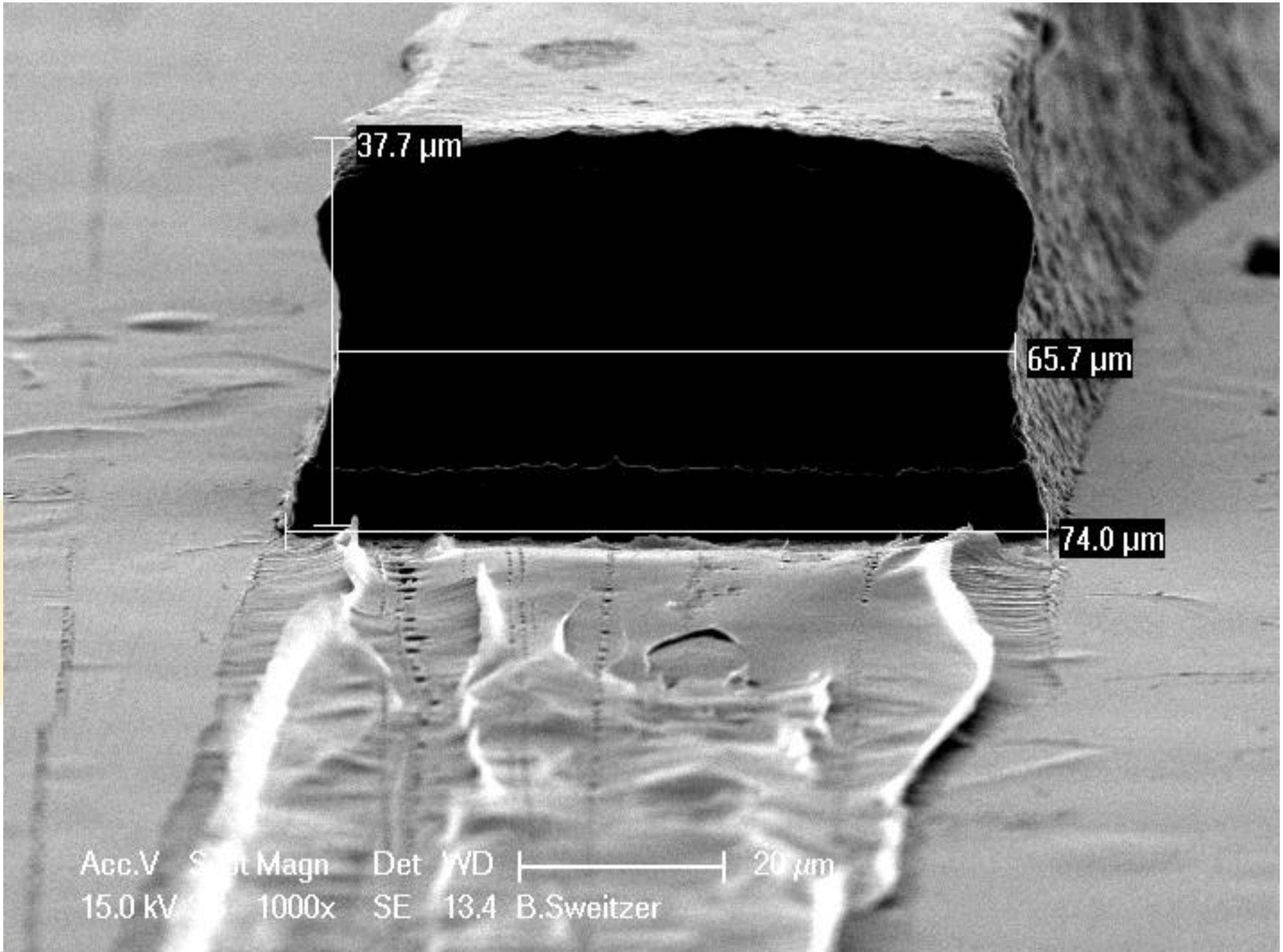


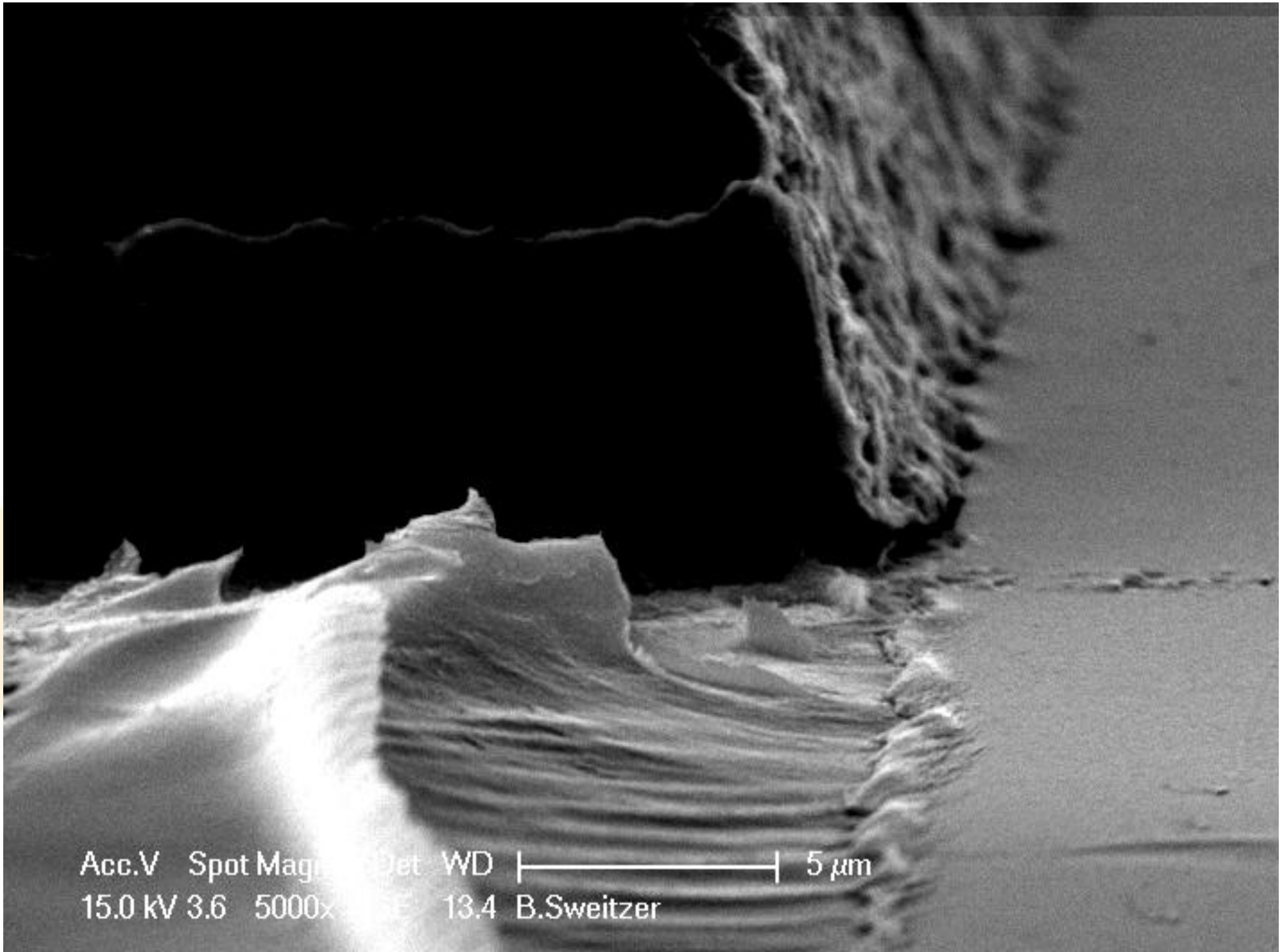
Trace

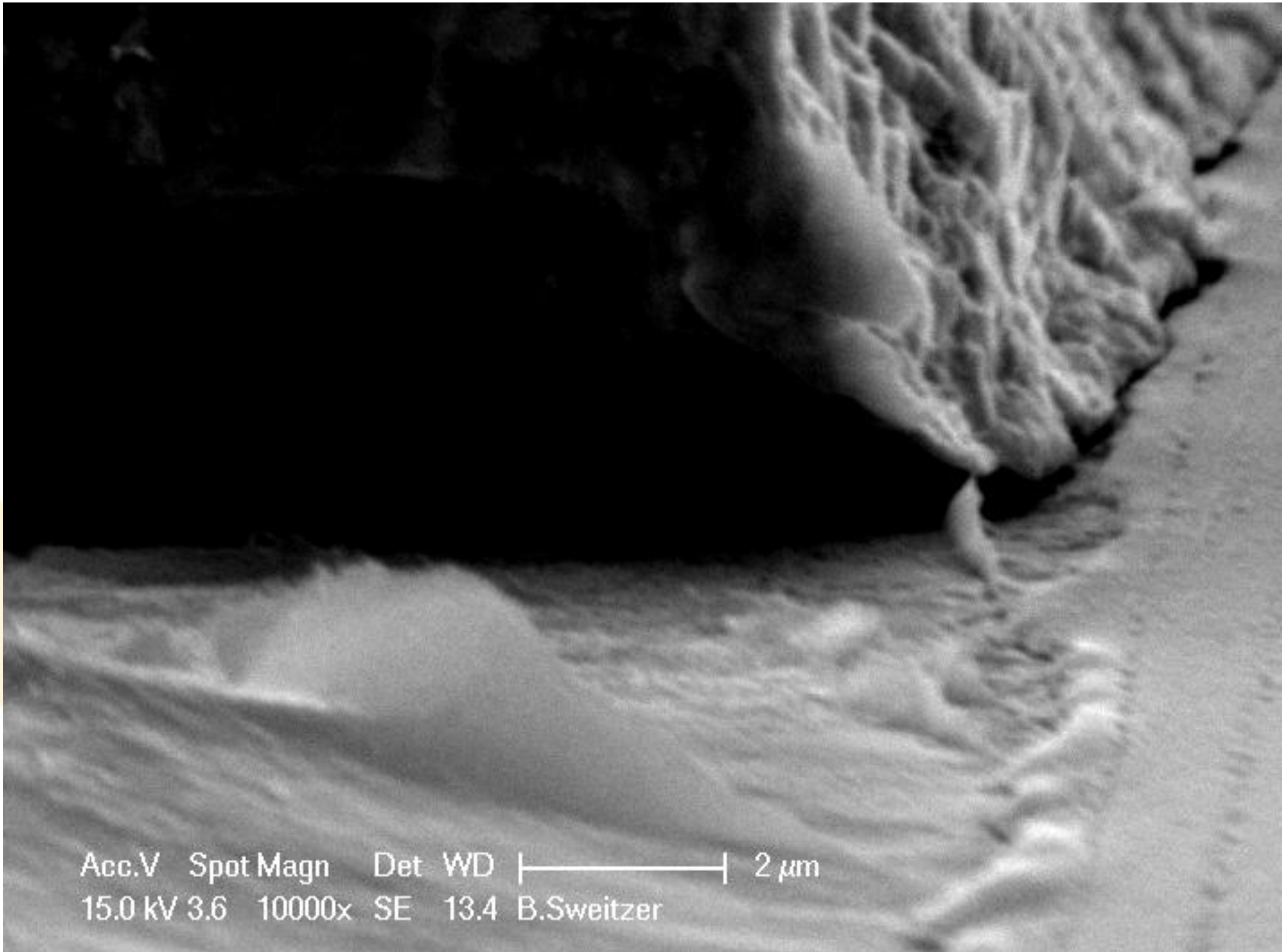
Peeled area



Acc.V Spot Magn Det WD 100 µm
15.0 kV 3.6 350x SE 13.4 B.Sweitzer


37.7 µm
65.7 µm
74.0 µm
Acc.V Spot Magn Det WD
20 µm
15.0 kV 1000x SE 13.4 B.Sweitzer


Acc.V Spot Mag
WD
5 µm
15.0 kV 3.6 5000x
13.4 B.Sweitzer



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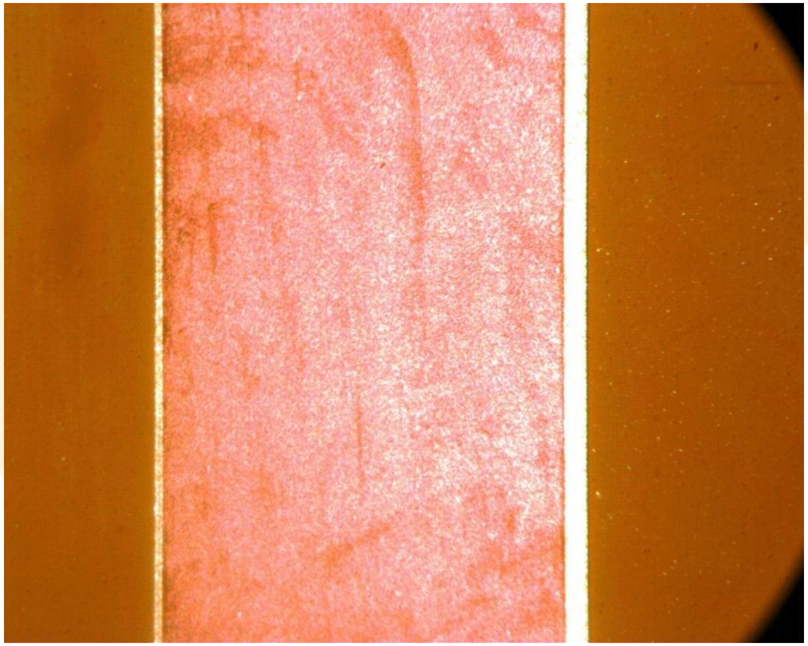
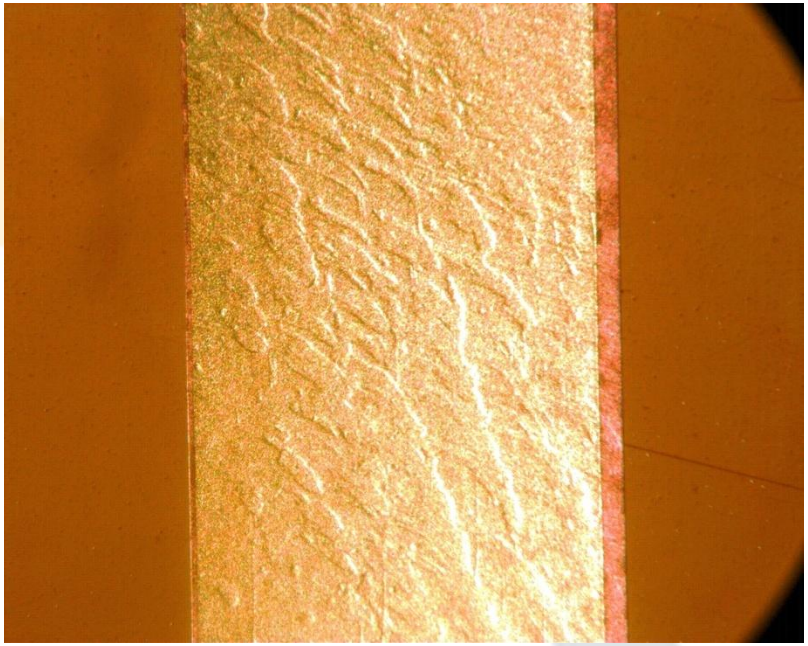
Factors affecting peel strength

- Copper thickness
  - 80% of the force goes into bending the copper.
- Peel angle
  - Depends on the intrinsic adhesion
- Film thickness
  - For double-sided coupons, not much…
- Backside reinforcement
  - Depends on the peel angle and intrinsic adhesion
  - Required for thicker copper at 90°
- Die-cut vs. etched
  - Can go up or down
  - Beware of failure mode change
- Etched conductor width
  - Not necessarily…
- Surface finish
  - Yes, but not in the way you might expect

ENIG selectively plated on 15µm x 3mm traces to either protect or expose Cu/PI interface to chemistry

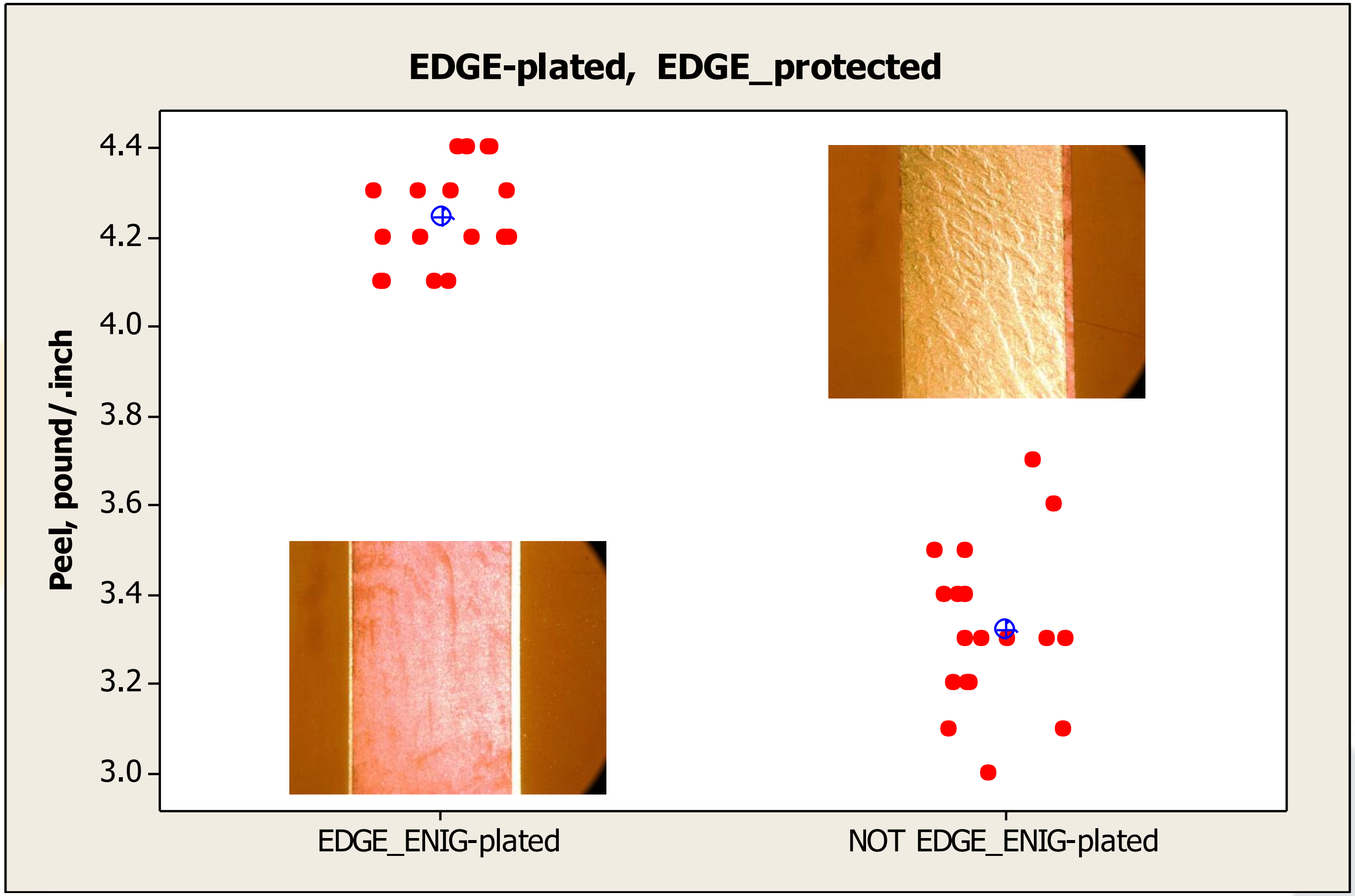


Edge-plated with ENIG



Edge-protected

Results


EDGE-plated, EDGE_protected
Peel, pound/.inch
4.4
4.2
4.0
3.8
3.6
3.4
3.2
3.0
EDGE_ENIG-plated
NOT EDGE_ENIG-plated

Why is peel value higher when the Cu/PI interface is accessible to chemical attack?

- Chemical intrusion is not part of the mechanism.
- The additional thickness of metal (nickel) doesn’t raise the value in the way you might expect.
- Theory: the high modulus of Ni stiffens the conductor and drives the crack to propagate in a different plane.

How does a deposited adhesiveless FCCL compare to other adhesiveless products?

- Double-sided Adhesiveless FCCLs of 35µm copper/25µm PI configuration were imaged with 3mm (1/8”) traces, plated with 4µm electroless nickel plus immersion gold, subjected to various conditioning regimes and peeled.
  - One deposited sample
  - Two laminated or cast materials

Peel after conditioning

- As received (method A)

Peel after conditioning

- As received (method A)
- After 10sec/288C solder float (method C)
  - – No-lead reflow increases thermal stress of soldering. For this reason, the following evaluation utilized five consecutive cycles of this condition.

Peel after conditioning

- As received (method A)
- After five 10sec/288C solder floats
- Heat aging
  - COF customers ask for 168hr/150C data.
  - Automotive customers want 1000hr/150C.
- Sheldahl developed an accelerated test of 72hr/210C to simulate the 1000hr/150C condition on double-sided material.
  - It is only applicable to double-sided materials.

Peel after conditioning

- As received (method A)
- After five 10sec/288C solder floats
- Heat aging (210C for 72 hrs)

Humidity exposure

- Peel is often tested after long-term exposure to 85C/85%RH, up to 1000hrs.
- The IC industry began testing the reliability of metalization on chips by pressure cooker exposure, one atmosphere of steam, which is 121C. Exposure times range up to 168hrs.

JEDEC's JESD22-A102-C

2 Scope

This test method applies primarily to moisture resistance evaluations and robustness testing. Samples are subjected to a condensing, highly humid atmosphere under pressure to force moisture into the package to uncover weaknesses such as delamination and metallization corrosion. This test is used to evaluate new packages or packages that have undergone changes in materials (e.g. mold compound, die passivation) or design (e.g. die/paddle sizes). However, this test should not be applied on laminate or tape based packages i.e. FR4 material, polyimide tape or equivalent.

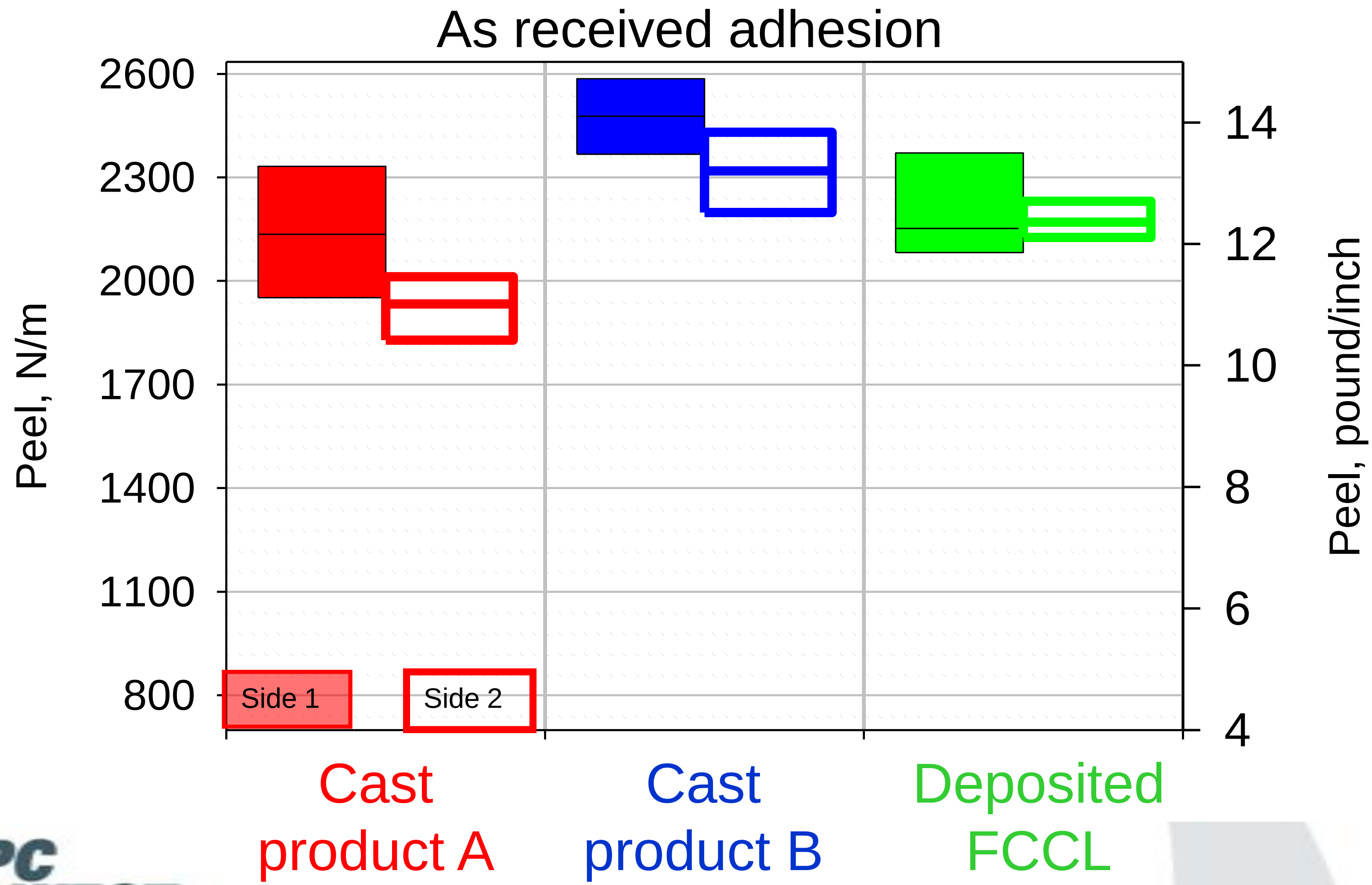
Some cautions should be considered when performing this test and evaluating test results. Failure mechanisms, both internal (e.g., due to plastic package swelling from saturation) and external (e.g. dendritic growth of conducting material between leads), may be produced which are not applicable to the intended application use conditions. Most semiconductor components are not rated for field applications conditions exceeding 95% RH, including condensing moisture such as rain or fog. The combination of high humidity, high temperature (>T_g) and high pressure may produce unrealistic material failures because absorbed moisture typically decreases the glass transition temperature for most polymeric materials. Extrapolation of autoclave test results to arrive at an application life should be accomplished with care.

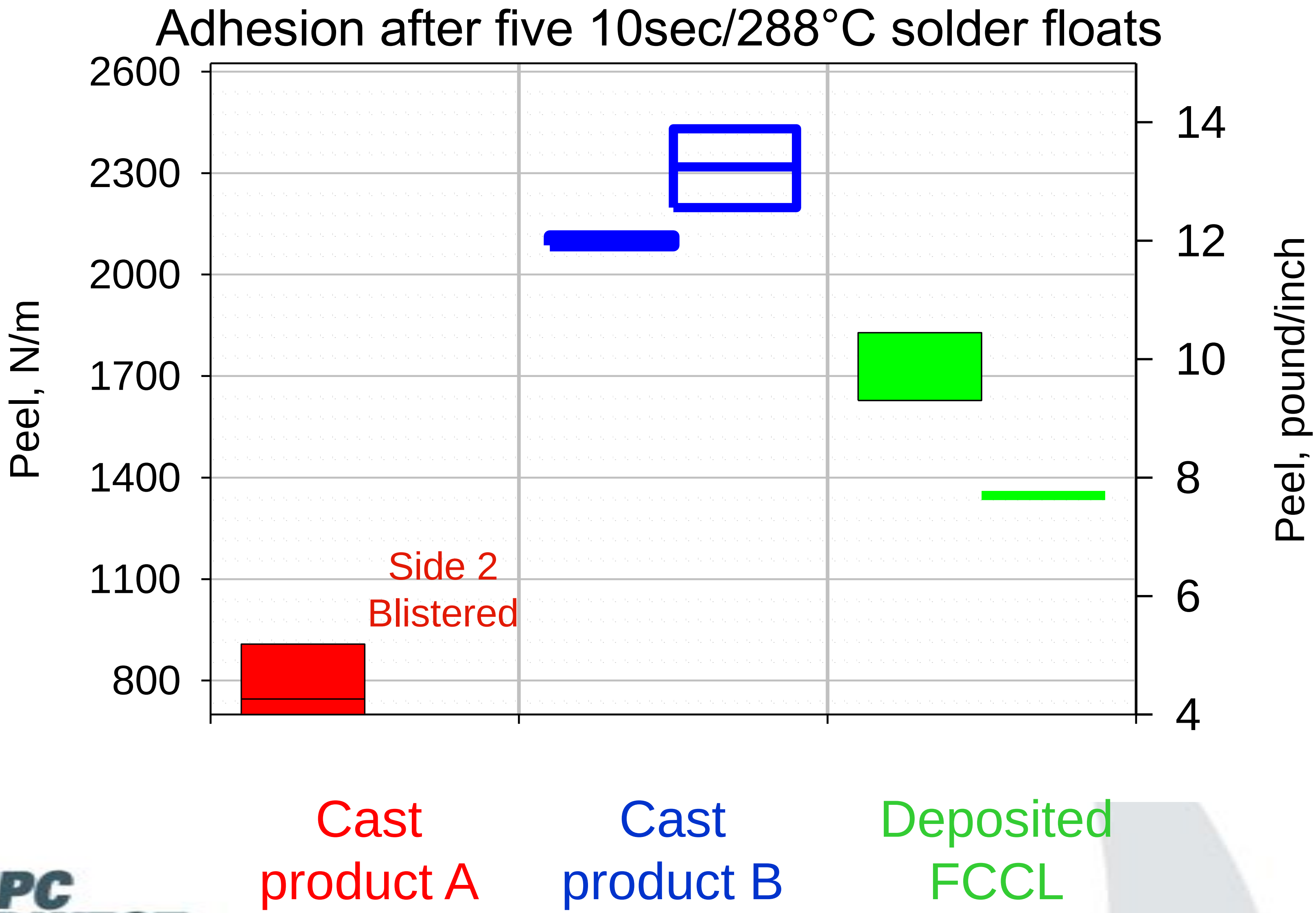
Peel after conditioning

- As received (method A)
- After five 10sec/288°C solder floats
- Heat aging (210C for 72 hrs)
- Pressure Cooker (96hrs/121C)

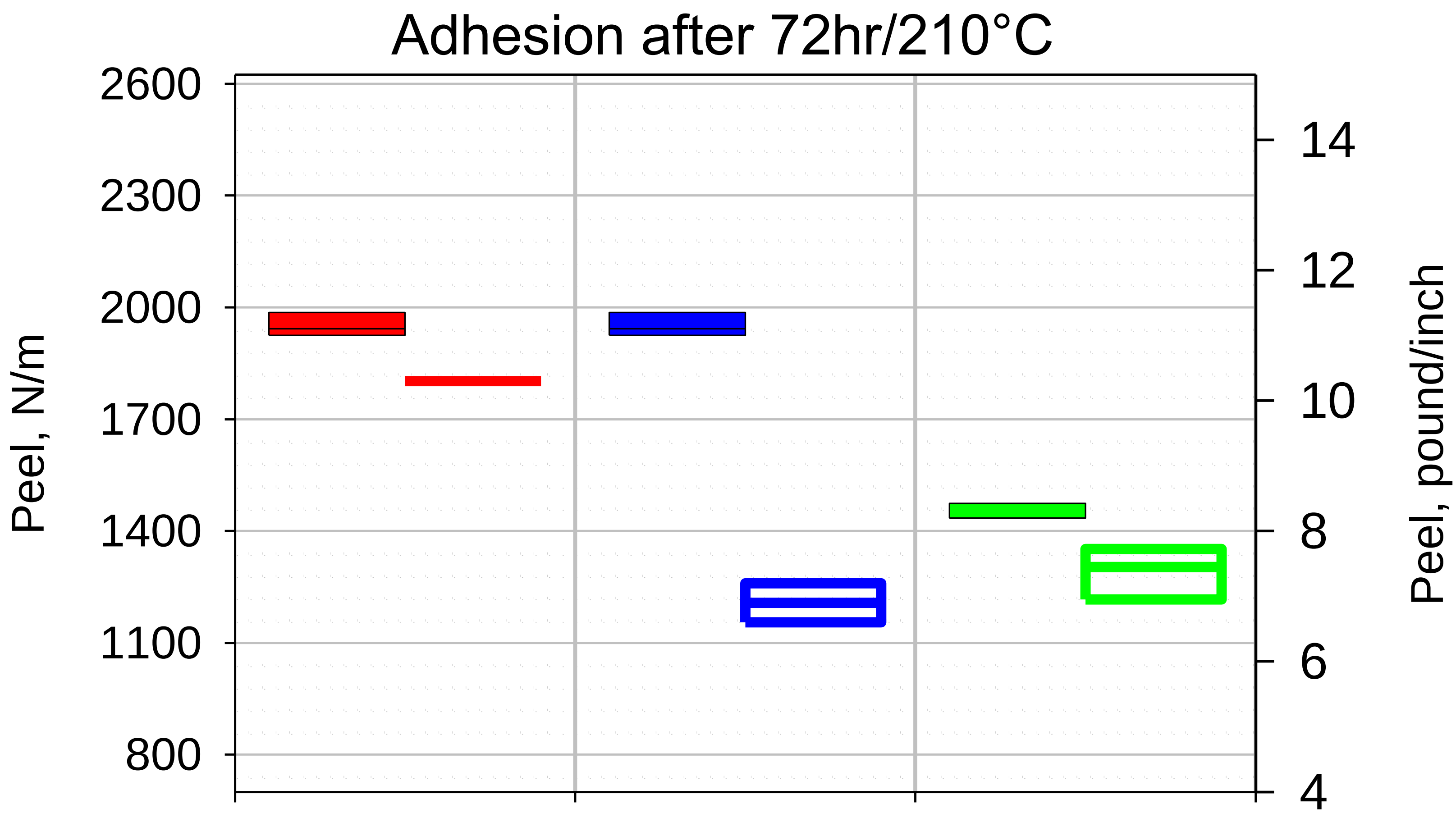
After ENIG plating

Peel after ENIG plating





Adhesion after five 10sec/288°C solder floats
2600
2300
2000
1700
1400
1100
800
Peel, N/m
14
12
10
8
6
4
Peel, pound/inch
Side 2
Blistered
Cast
product A
Cast
product B
Deposited
FCCL



Cast product A

Cast product B

Novaclad® HA

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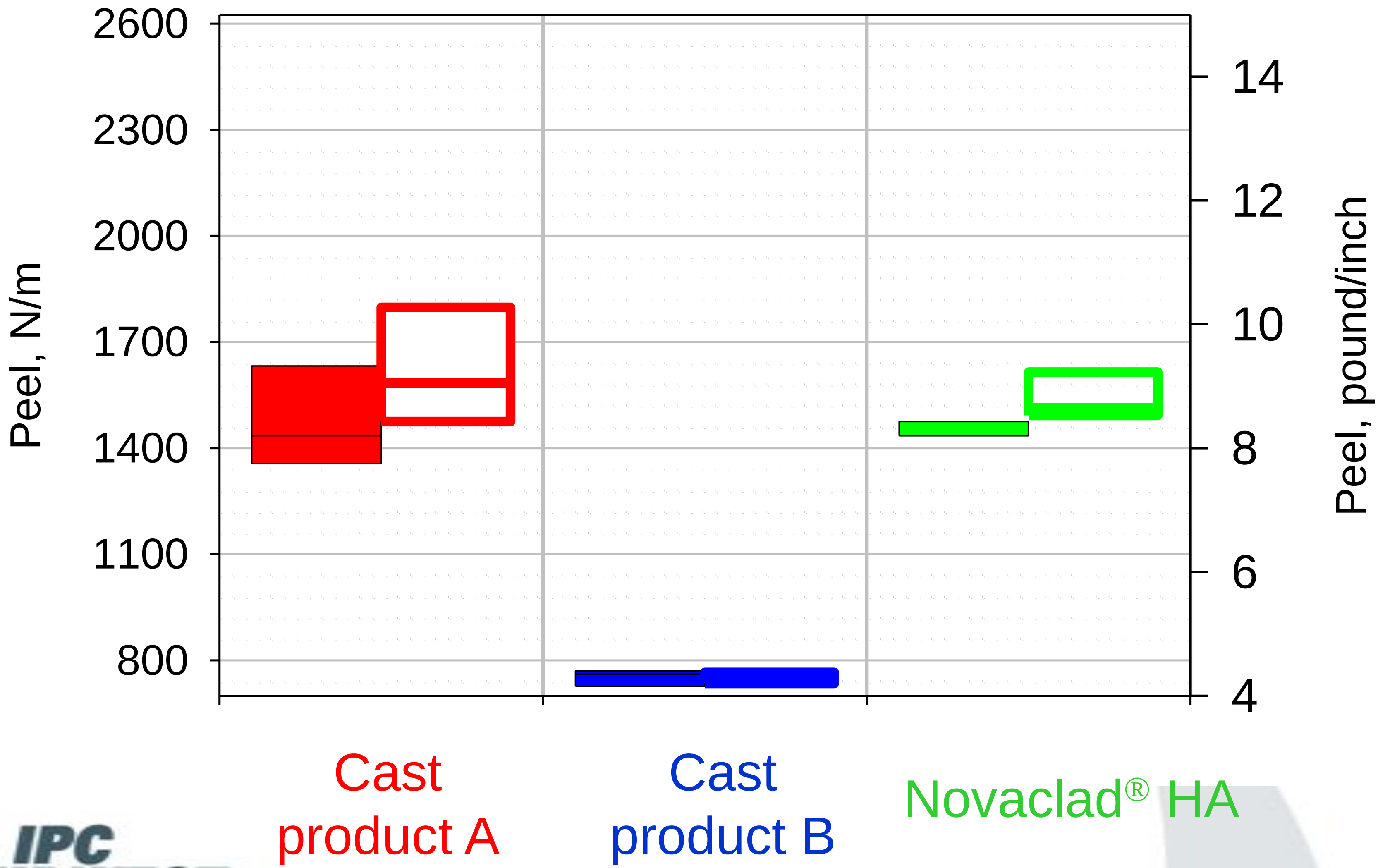
Adhesion after 96hr PCT



Conclusions

- Nuances of peel testing as applied to deposited adhesiveless FCCLs are easily understood. Most important factor is copper thickness.
- Deposited adhesiveless FCCLs compare favorably in adhesion to their cast or laminated cousins.

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