Extreme Soldering: You Can Do BGA

marshallh

Toorcamp 071214

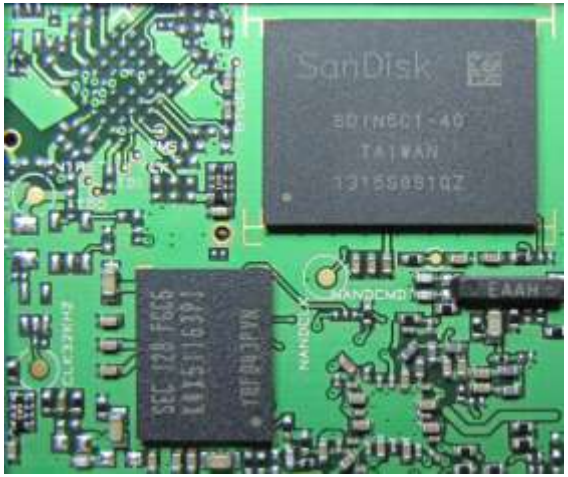
<video>

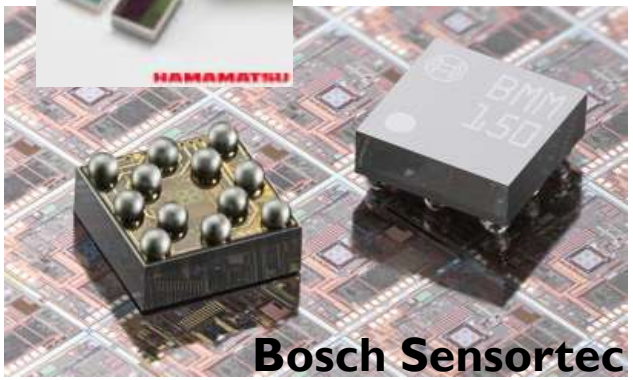

Lattice
ECP3
LSU3-001
VBUS
1V1
1V2
3V3
MADE IN CHINA

What I'll cover

- 1. Overview of BGA and surface mount
- 2. PCB design
- 3. Assembly / Rework

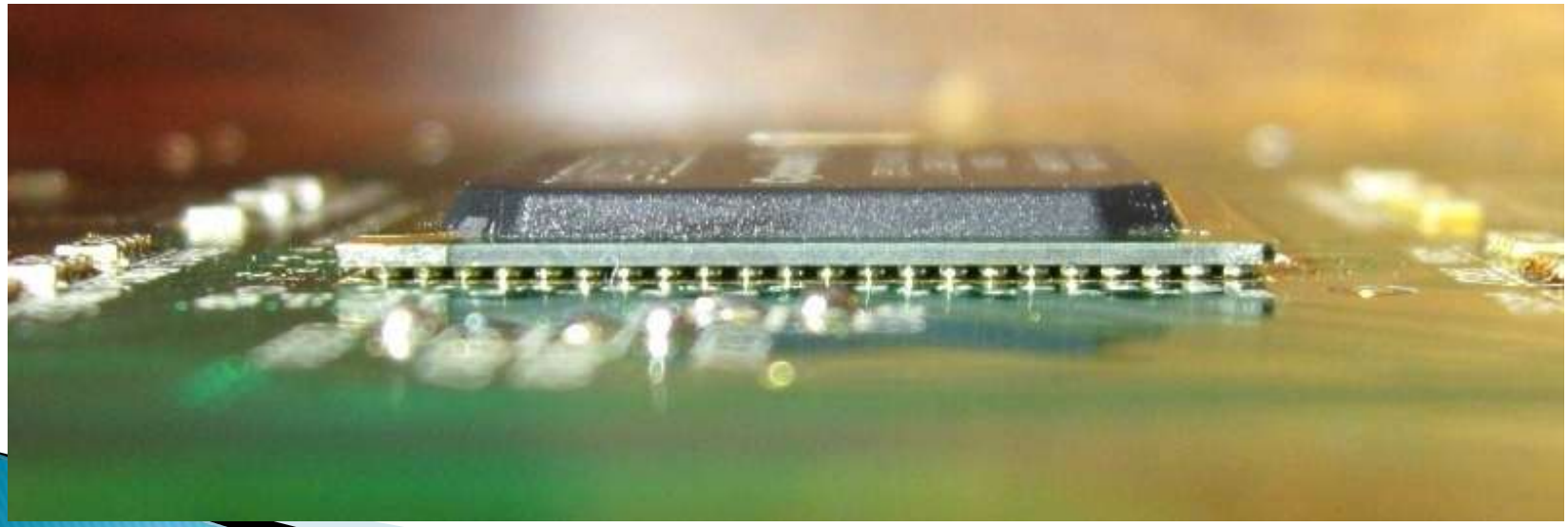
Package size evolution





No reason to be scared of BGA

- Much easier to assemble
- More compact
- Can use newer parts
- BUT, rework more difficult

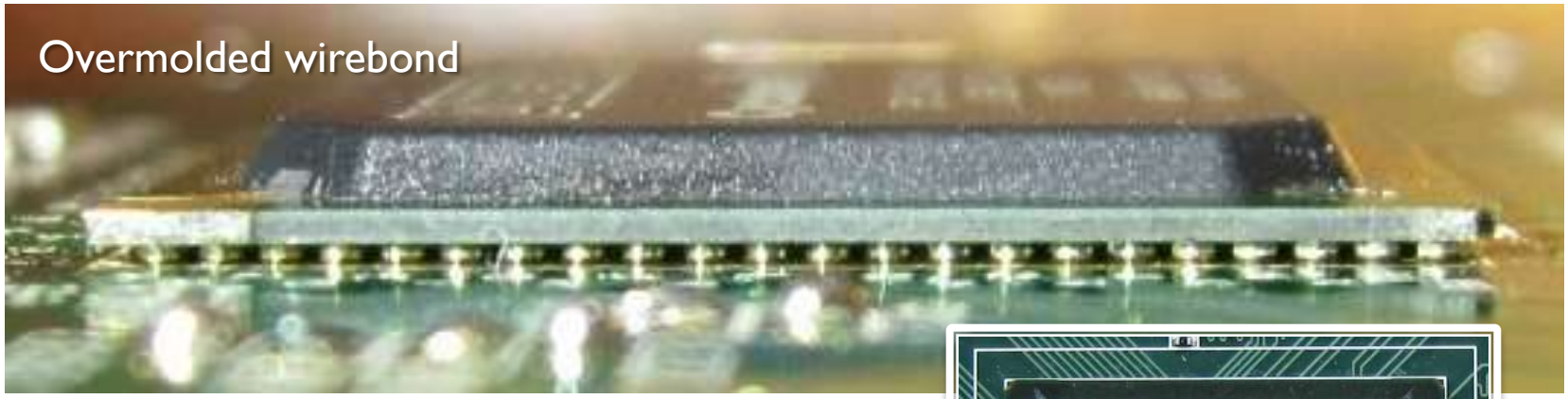


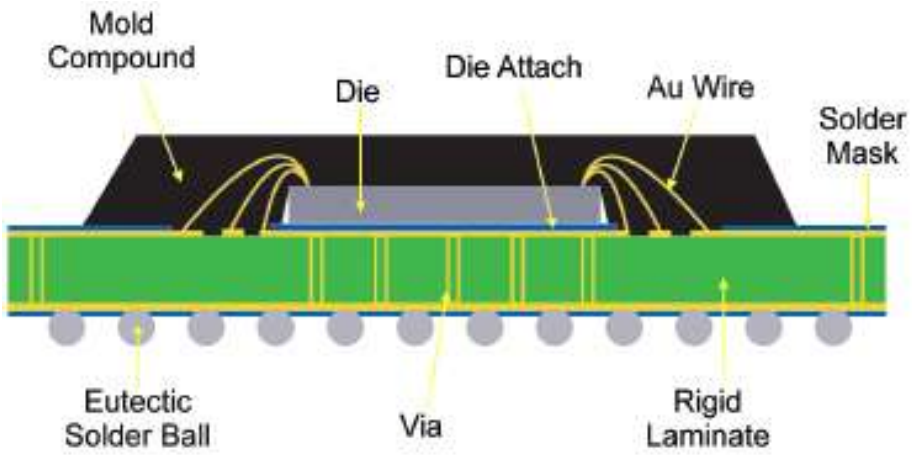
What is BGA

- Popular package for CPUs, memory, SoCs, interface chips
- High pin count, small space
- Can be difficult to "break out"
- Necessary for modern fast digital

- Quick, cheap 4layer services mean small BGAs are perfectly usable for prototyping

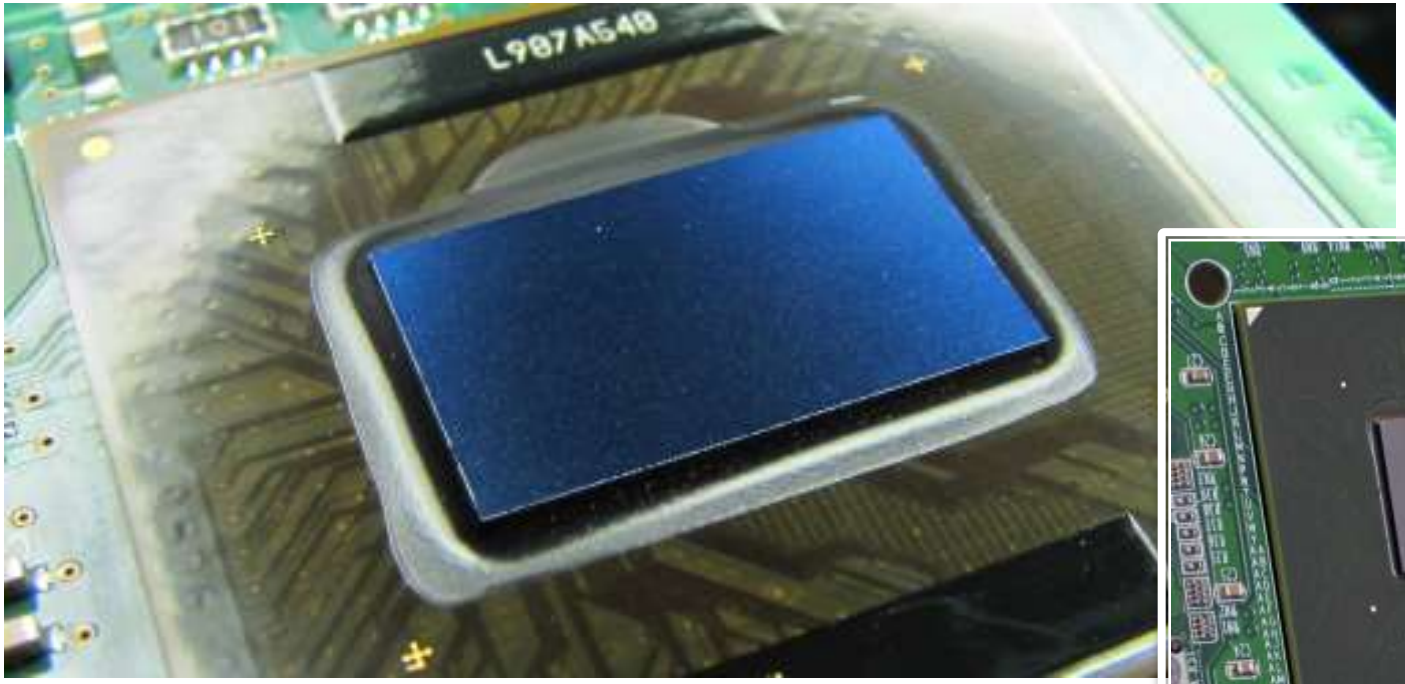
Variants of BGA packages





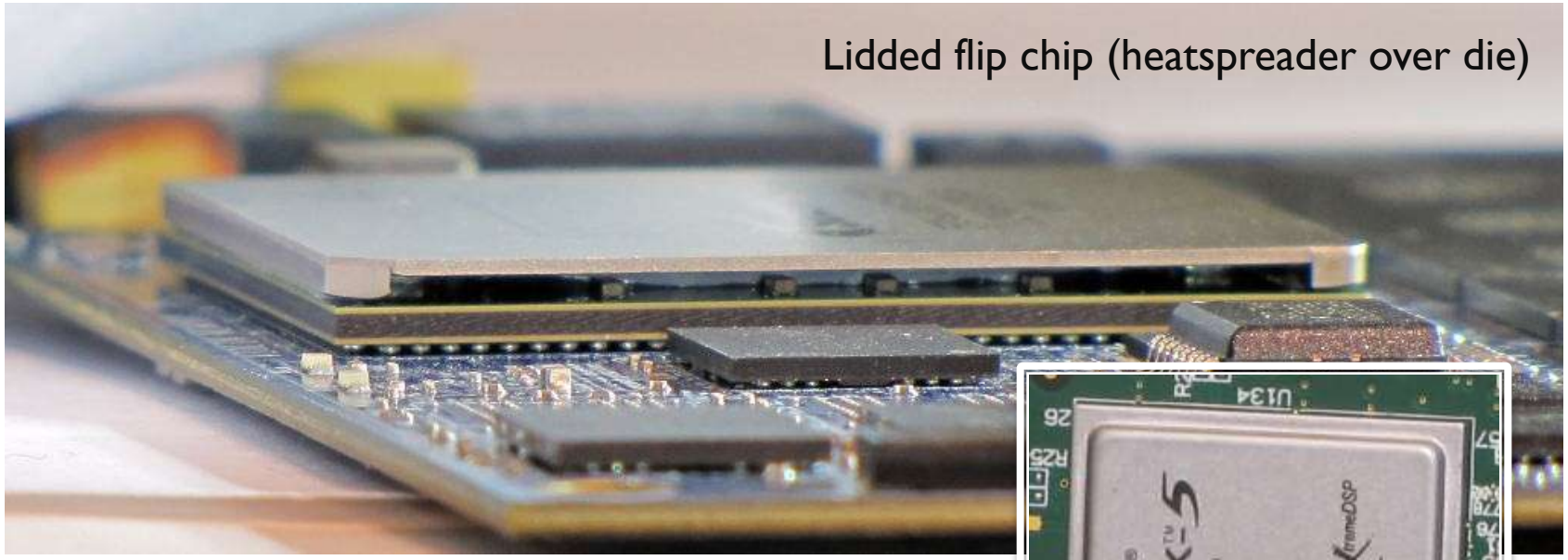
Cutaway diagrams © Amkor

Variants of BGA packages

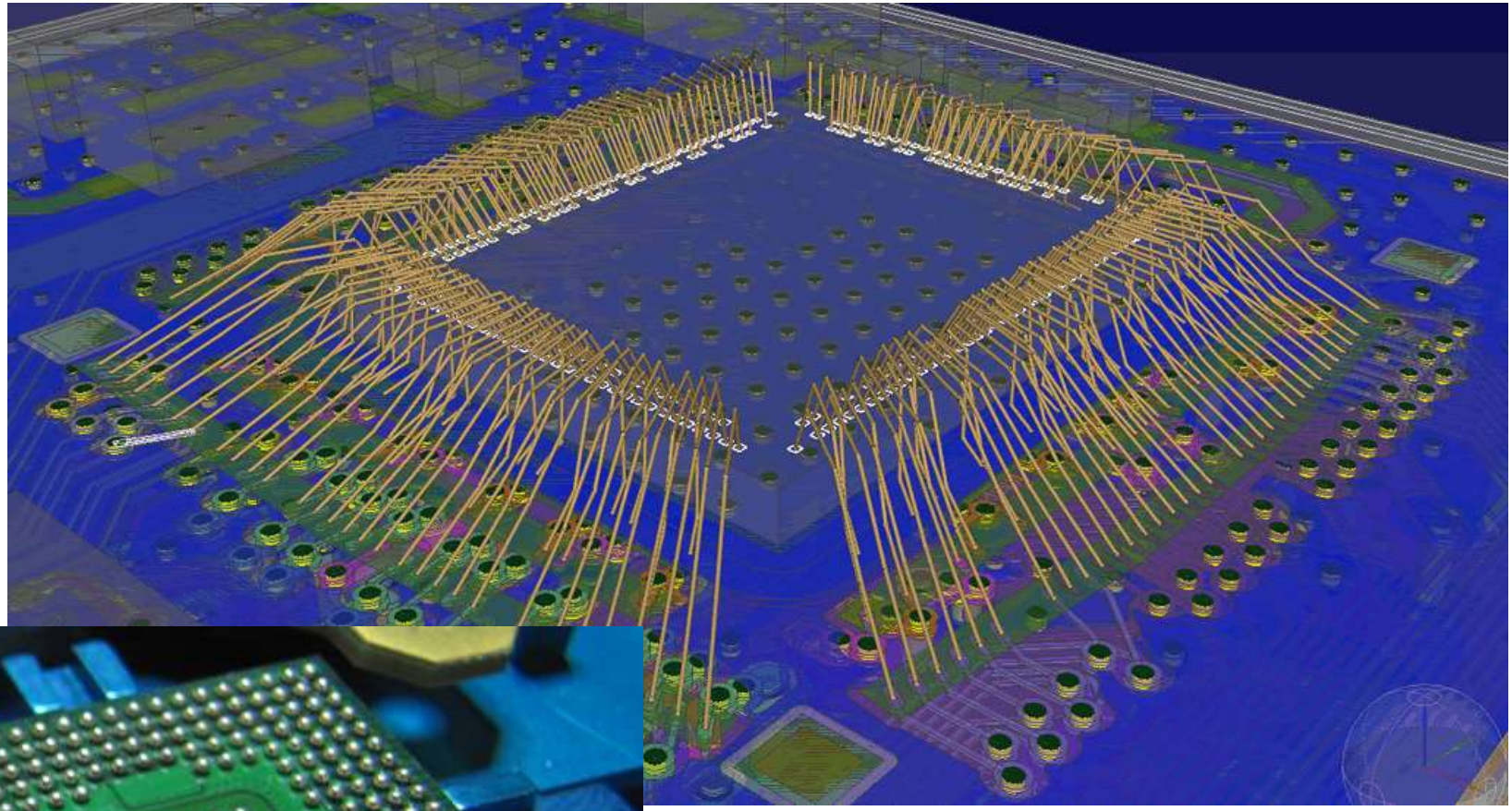


Lidless flip chip

Variants of BGA packages



Cutaway diagrams © Amkor



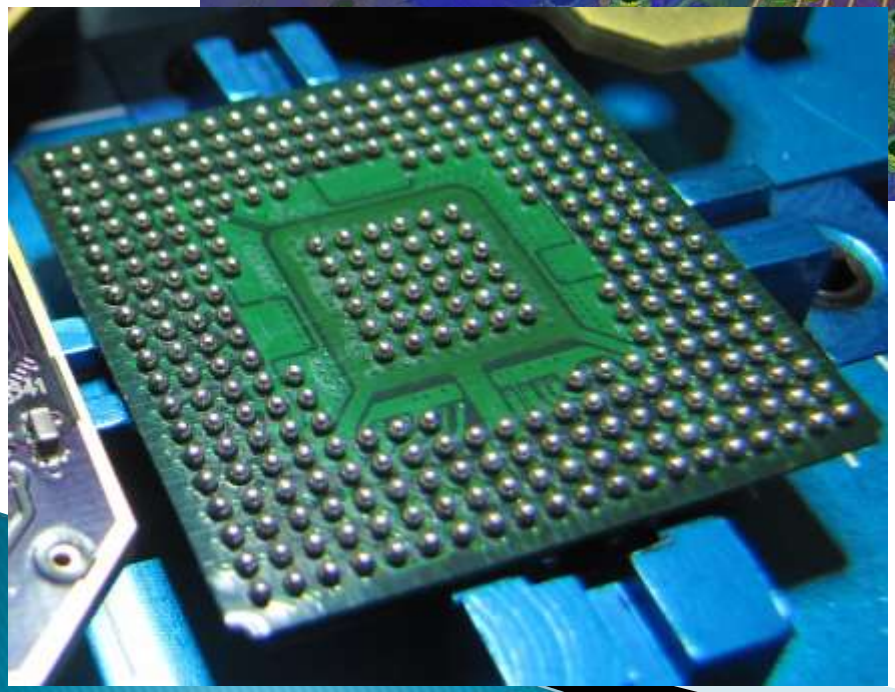
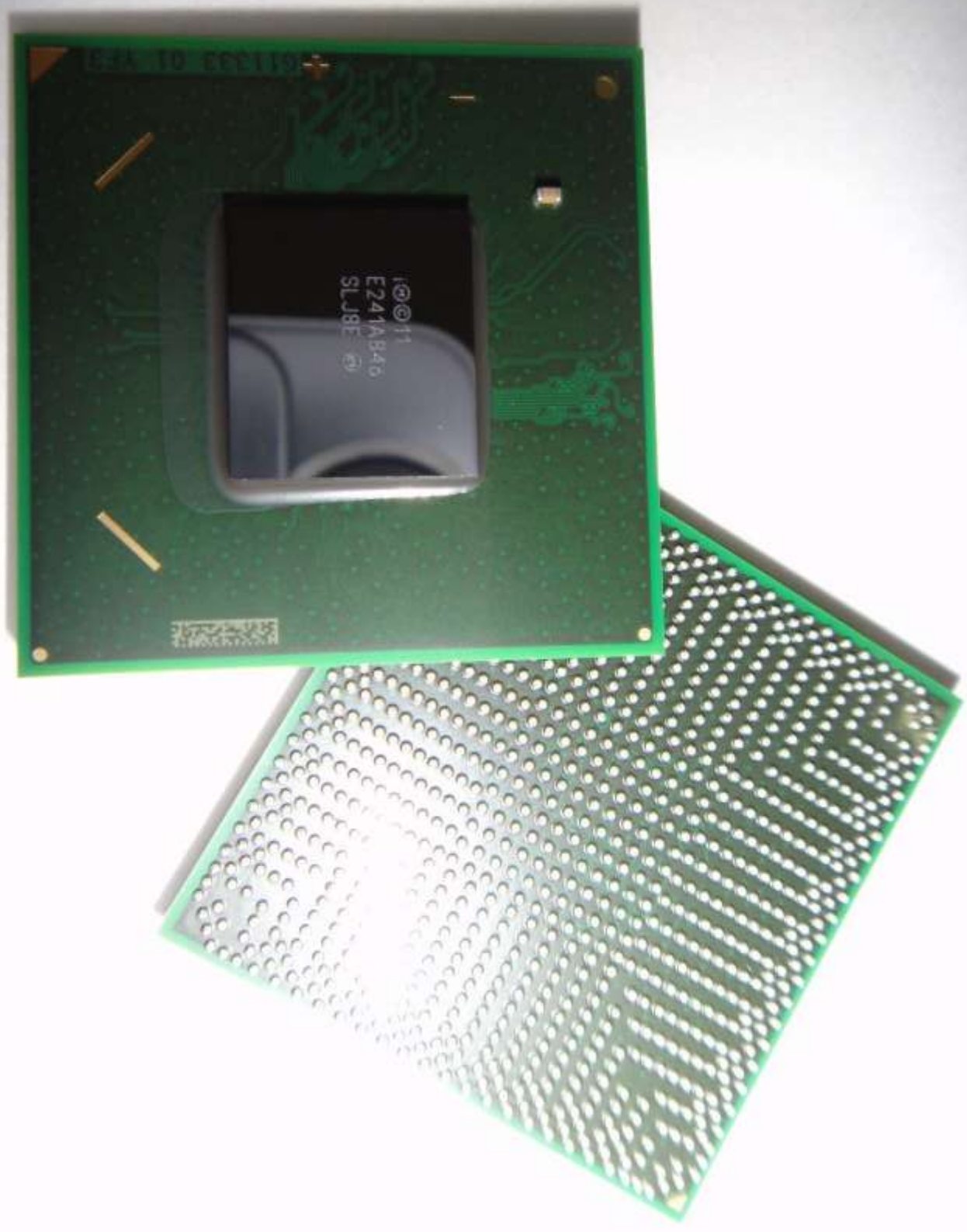


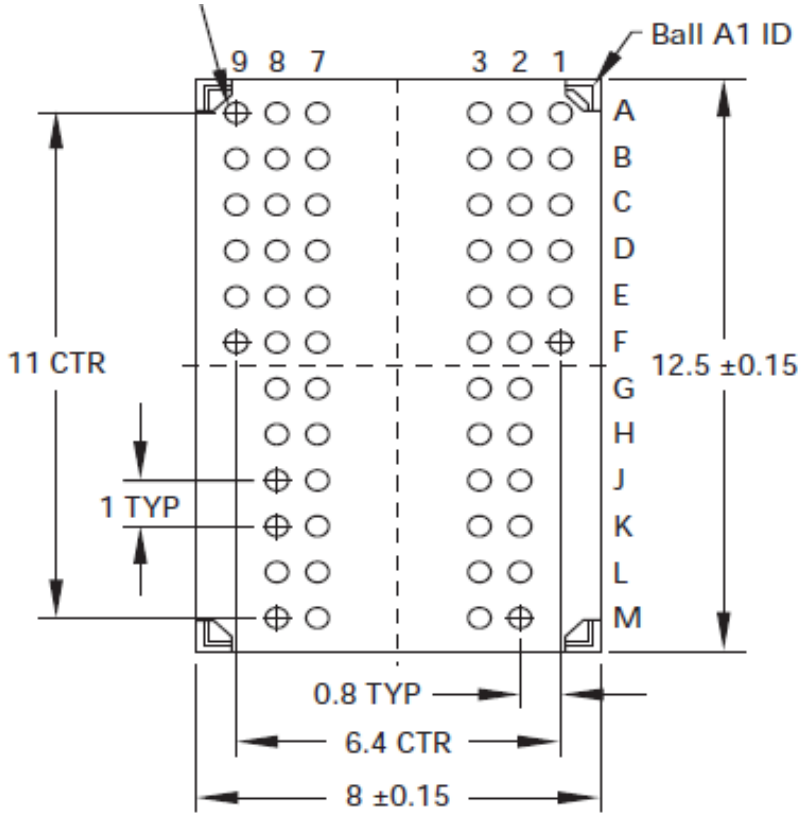
Image Zuken


i©©11
E241A840
SLJ8E

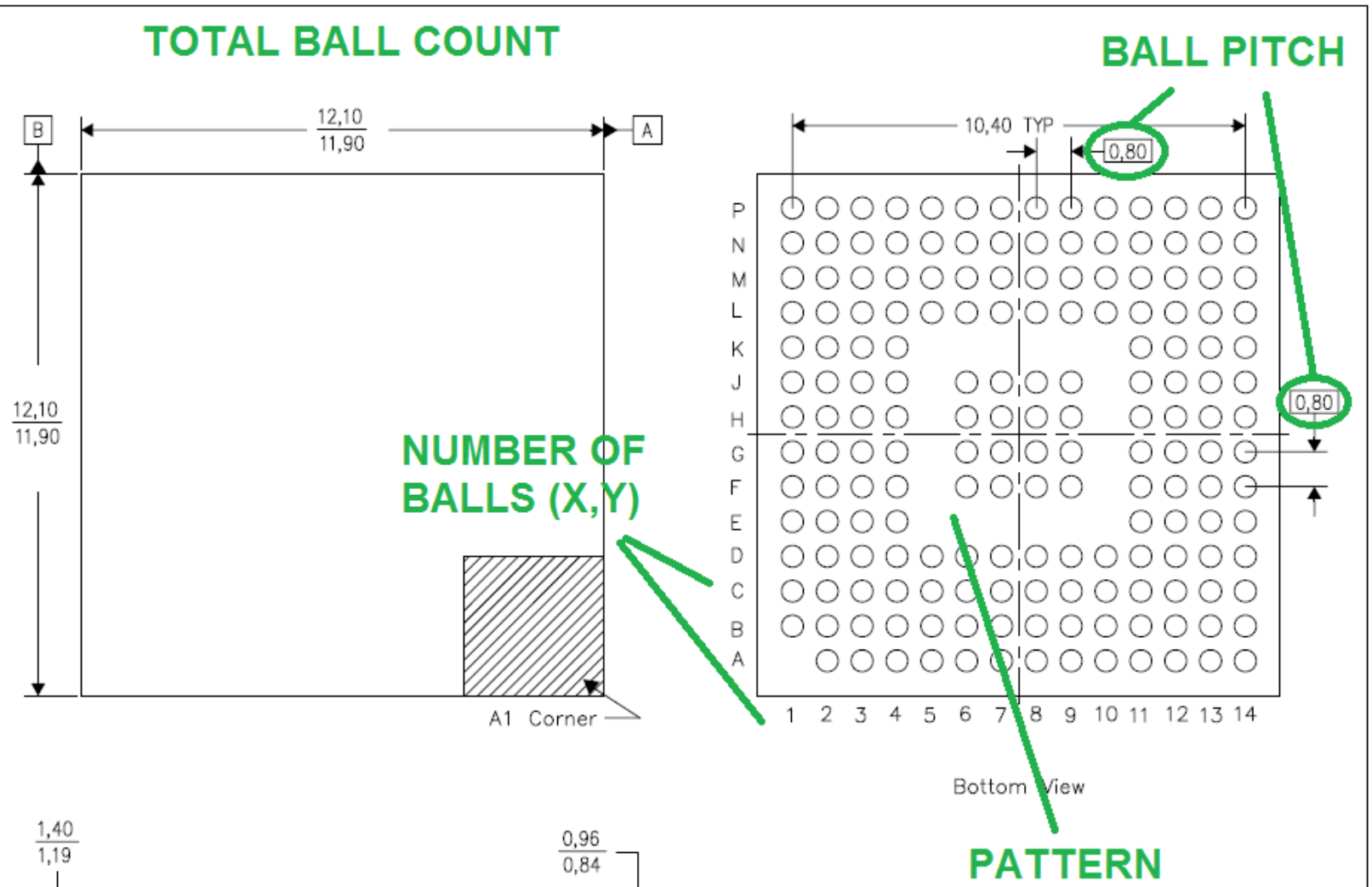
Footprint measurements

- Pitch
- Land size (usually function of pitch)
- Pattern (any voids)
- Total ball count

- Most packages have grid-aligned balls
- Horiz/vertical pitch may not be square



ZAY (S–PBGA–N175) PLASTIC BALL GRID ARRAY



Typical metrics

- 0.5mm (Low ball count, PoP)
- 0.8mm (SoC, DDR)
- 1.0mm (Large FPGAs)
- 1.27mm (Legacy devices)
- Total balls can range from 4 to over 1000-2000
- Leaded balls, leadfree (RoHS)

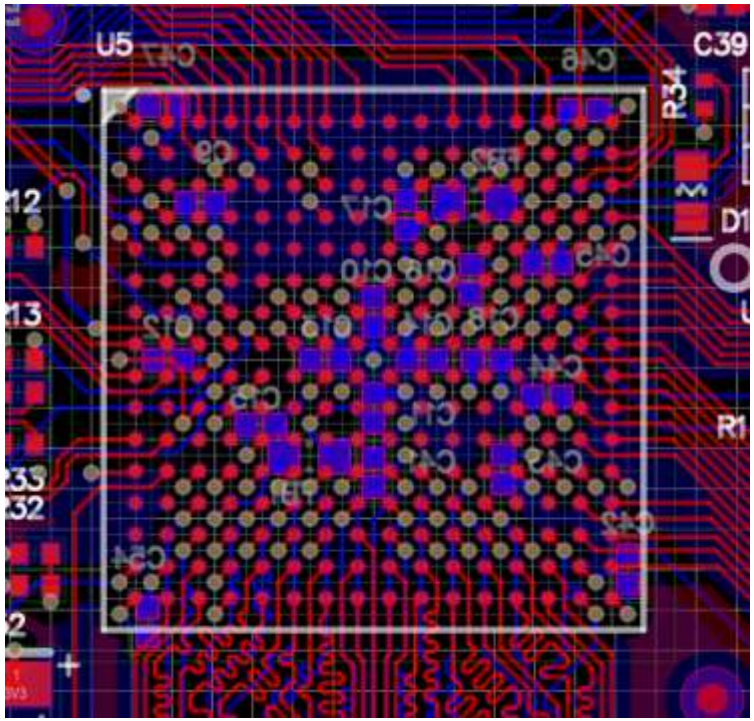
- Larger pitches much easier to break out

PCB layout for BGA

- Can be done in just about any package
- I've used Eagle, Altium, others used Kicad
- Hand routing essential for layer count
- Footprints easy, symbols not
- Typical high speed layout rules apply

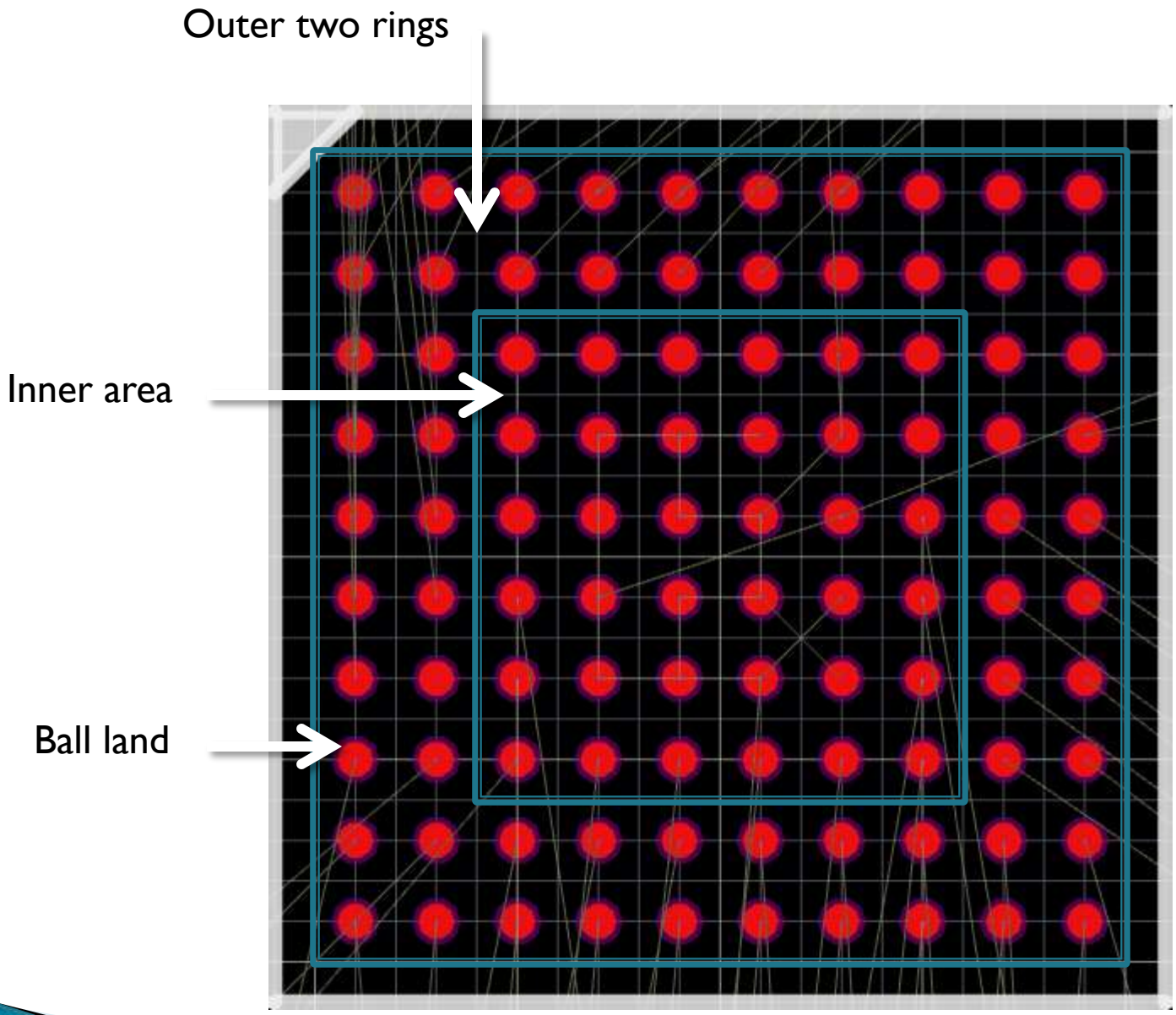
PCB specs required

- 4 layers is the sane minimum for most
- 256 balls possible on 4 layer
- 324 requires 6 layers
- 484 requires 8 layers
- For example a high end Stratix FPGA with ~1400 may take 16 layers
- ENIG, Immersion Silver
- PTH vs microvias

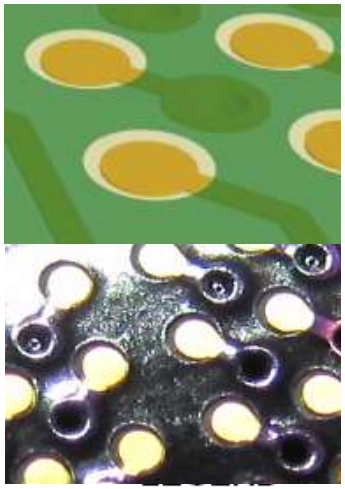


Layout process

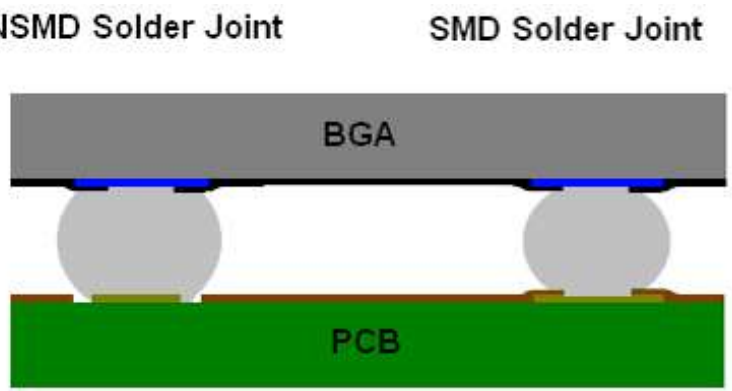
- Fanout all pads except 2 outer rings
- Next two rings via'd to bottom layer
- Ground, power fills
- Land diameter: 2/3 of ball diameter
  - Example: 1.0mm bga
    0.8mm balls
    0.48mm land size
- 1.0mm:
  - 13mil drill, 21mil diameter, 6mil trace/space
- 0.8mm:
  - 10mil drill, 18mil diameter, 5mil trace/space


Outer two rings
Inner area
Ball land

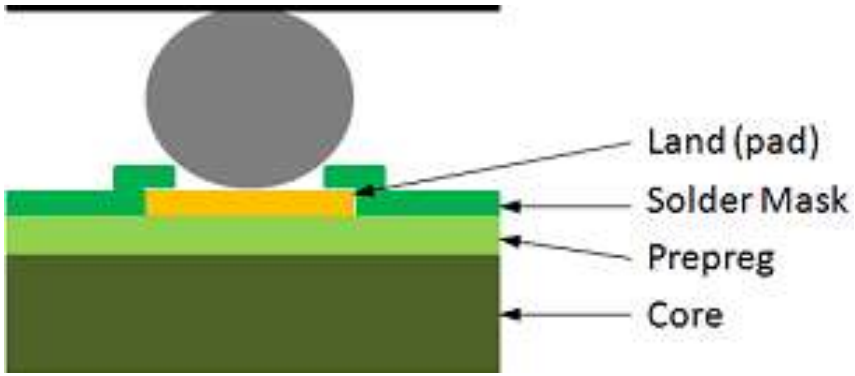
Ball land styles

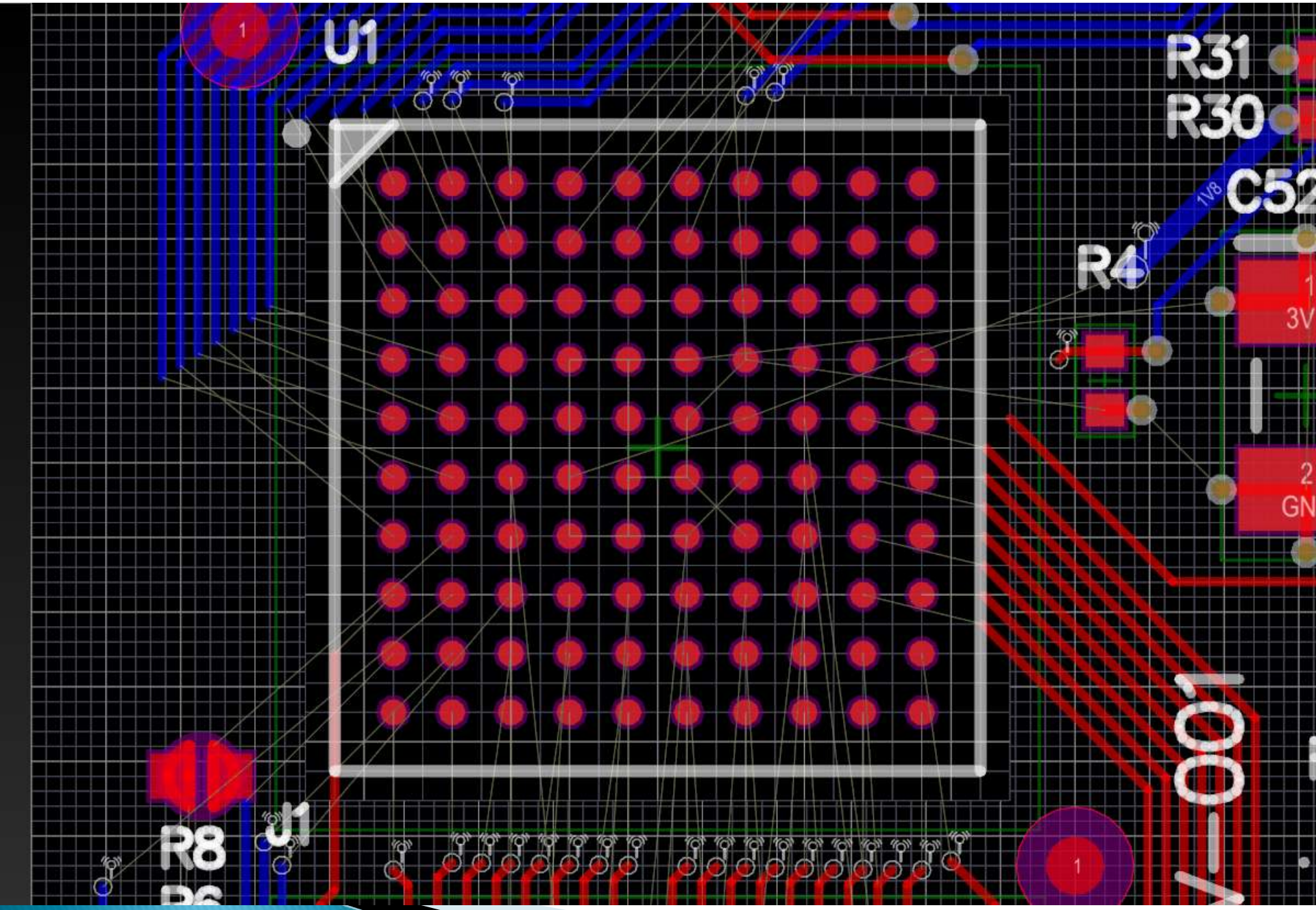


- NSMD (Non-solder mask defined)
  - Most common, allows solder to "grab" around copper



- SMD (Soldermask defined)
  - Used when not enough space

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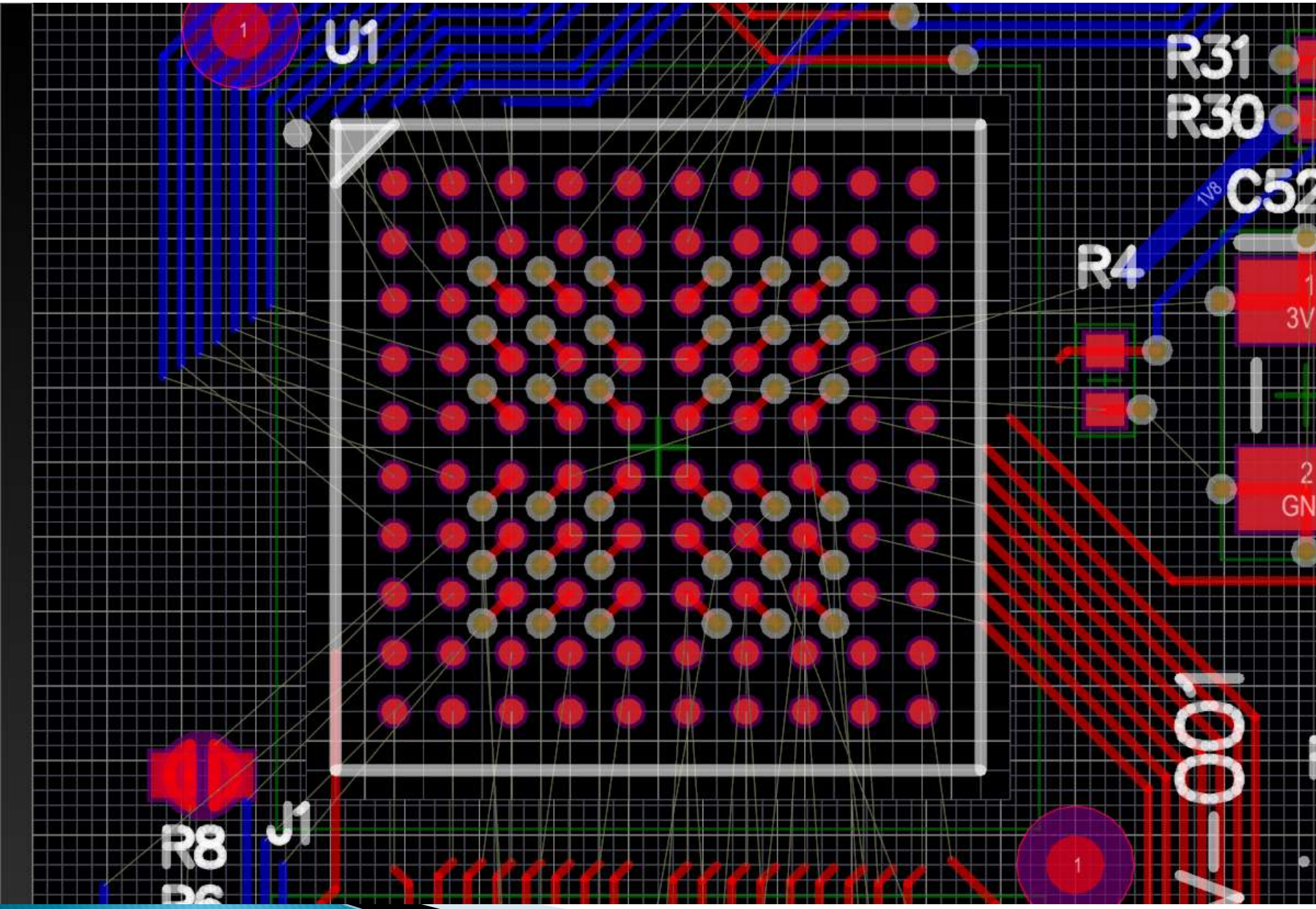
R31
R30
C52
1V8
R4
3V
GN
R8
J1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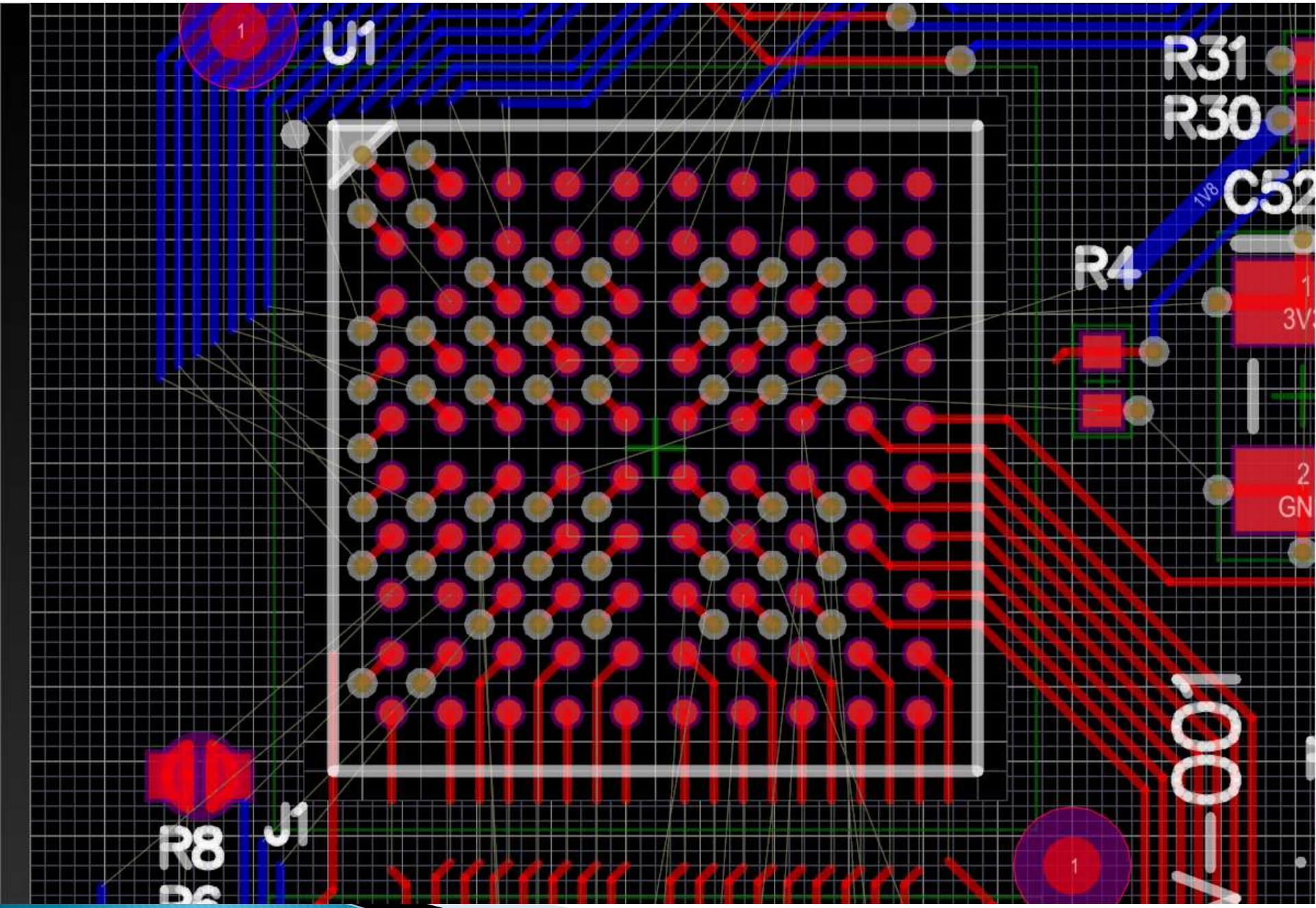
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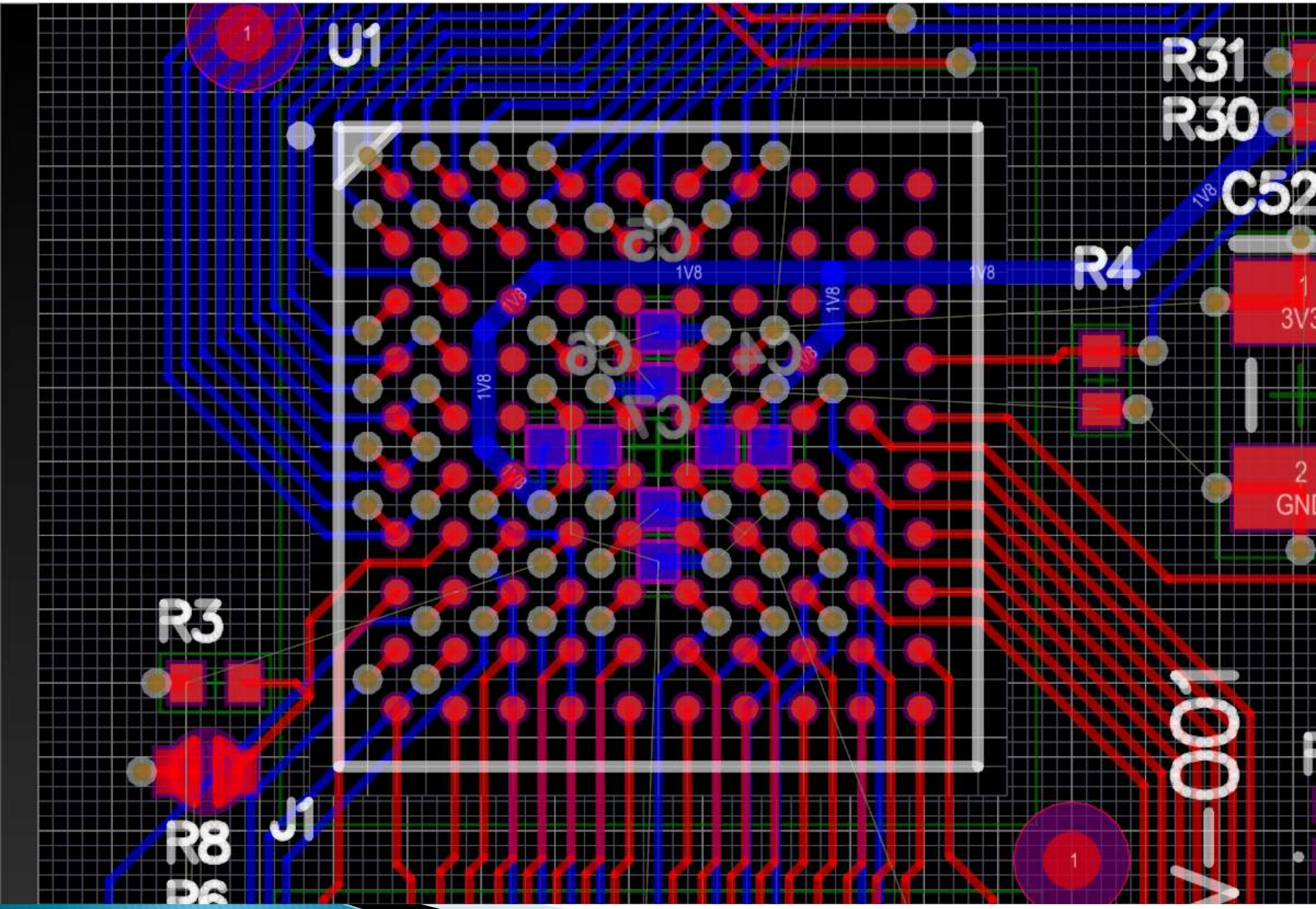
1V8
R4
3V3
GND
R8
J1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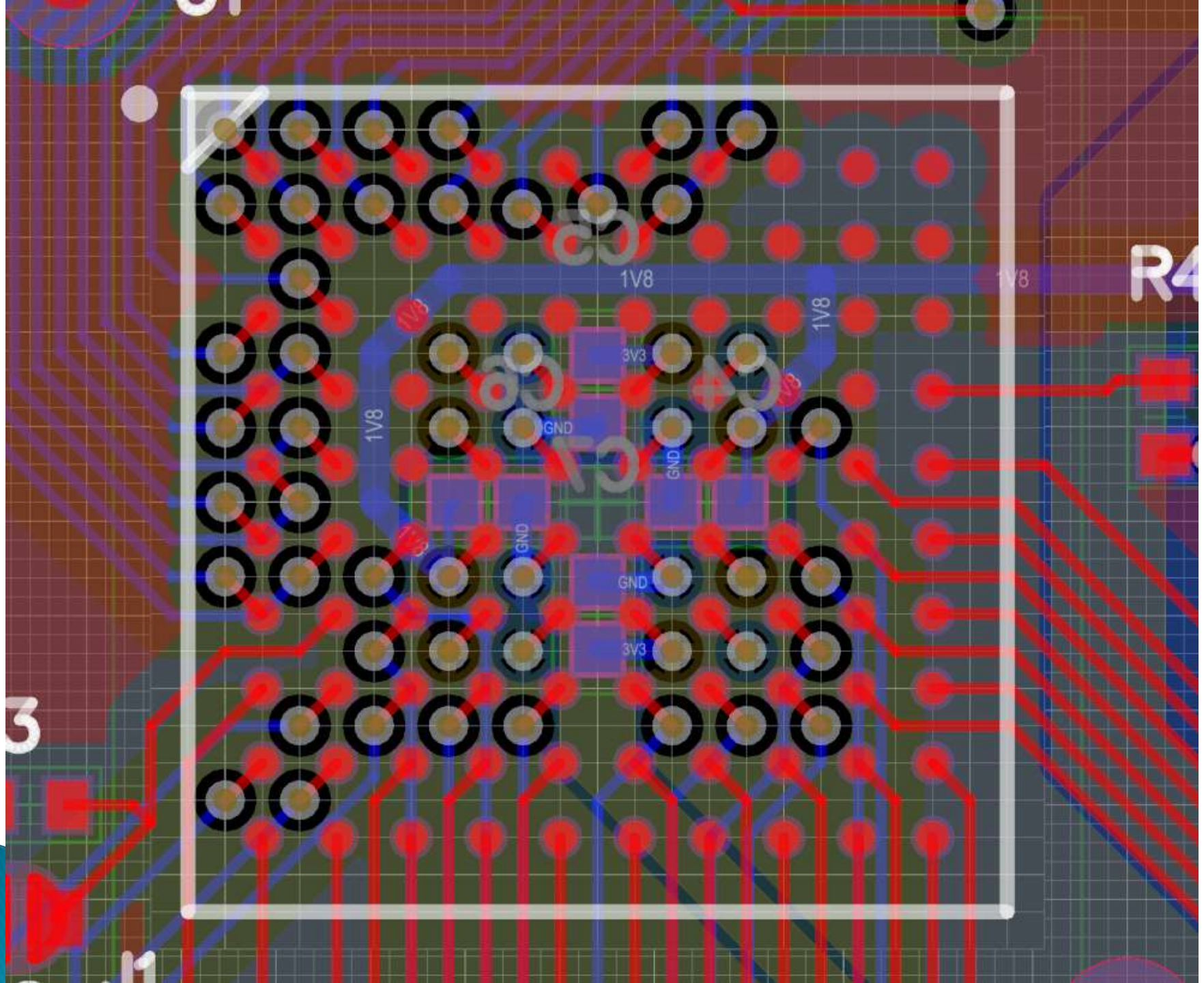
GND
R3
R8
J1
C3
C6
C4
C1
C2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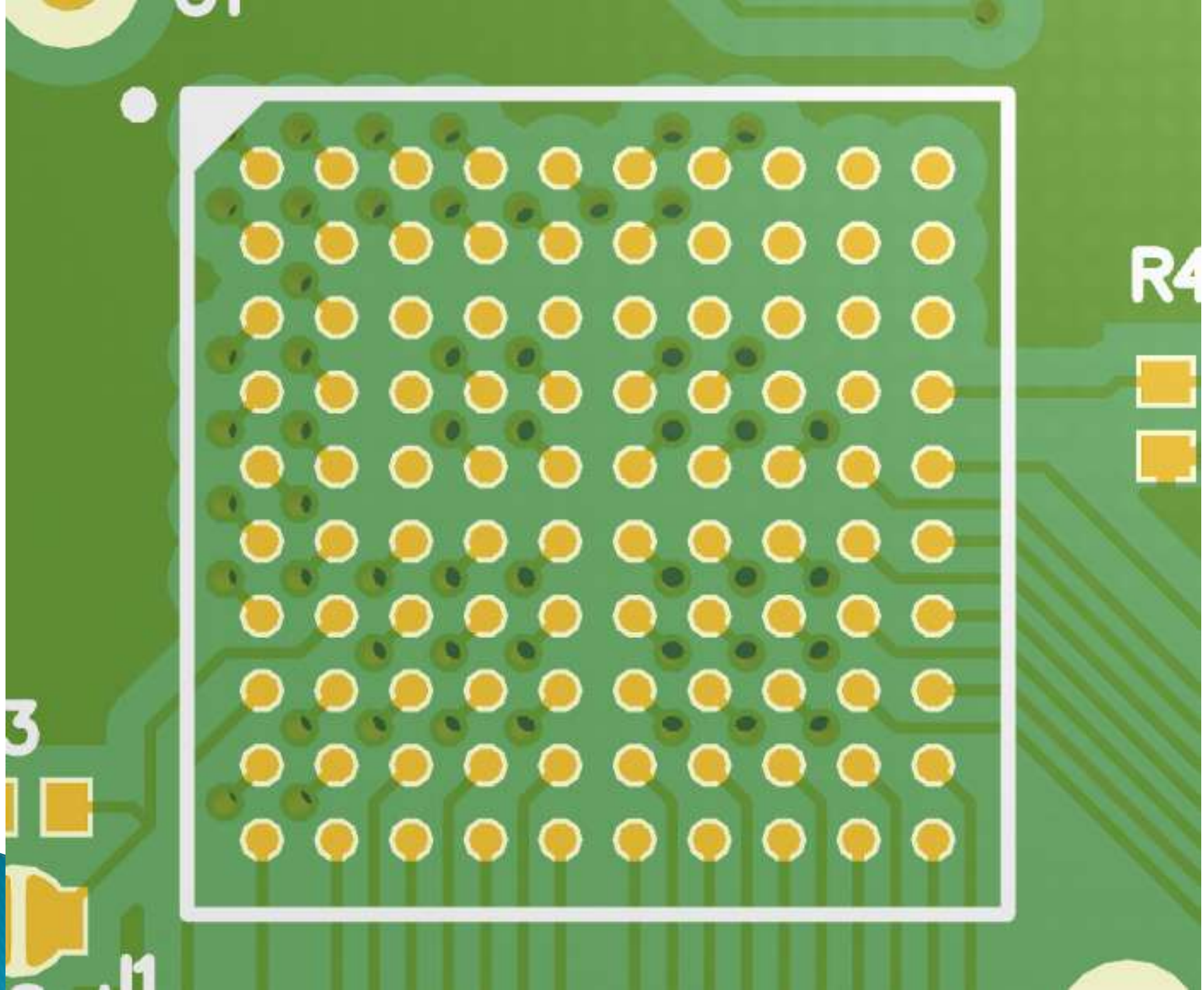
1V8
1V8
1V8
3V3
GND
GND
GND
GND
3V3
R4

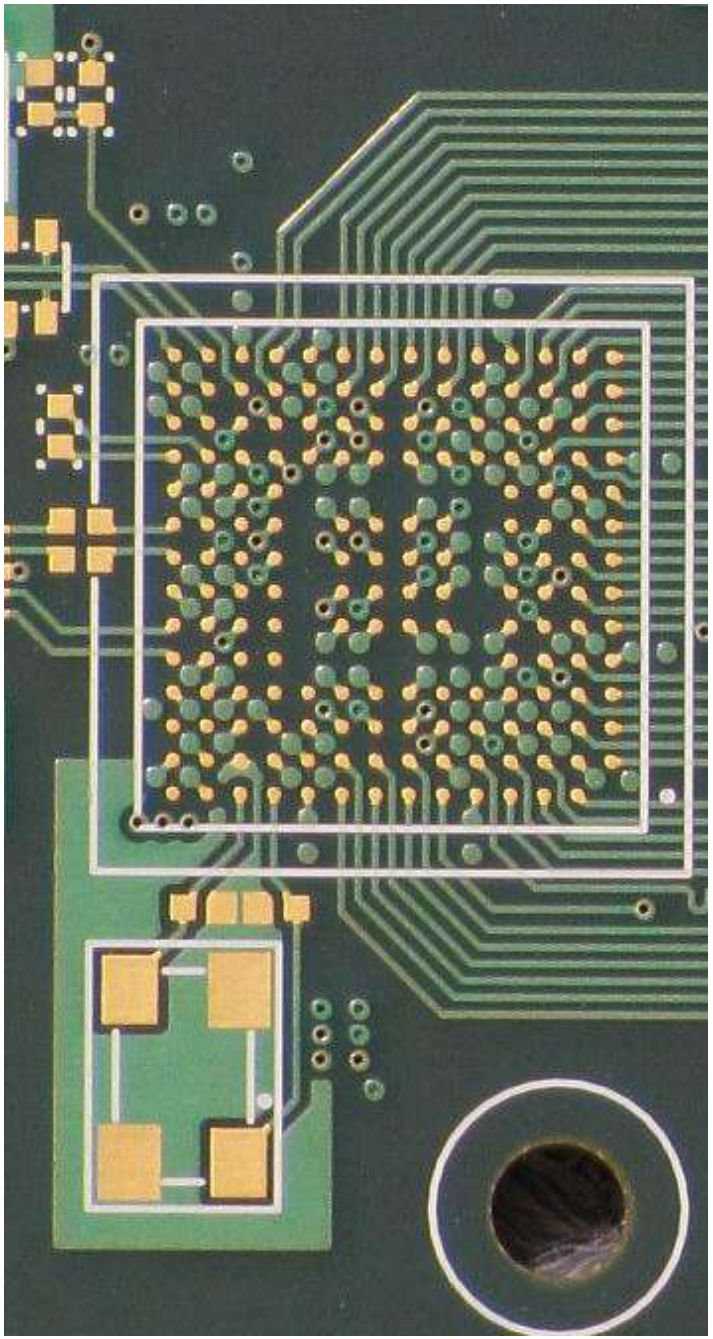

R4

Pads over vias?

- DON'T!
- Result: via steals solder, stressing joint, outgassing causes voids

- Real via-in-pad (VIP):
  - Plugged vias
  - Capped vias

- Aids bypass caps, costs $$$




0046-01_R03
S/N: 2610CN00004296

PCB Inspection

- 1. Soldermask-copper alignment
- 2. Ensure annular ring on all vias
- 3. Pad coplanarity
- 4. Plating

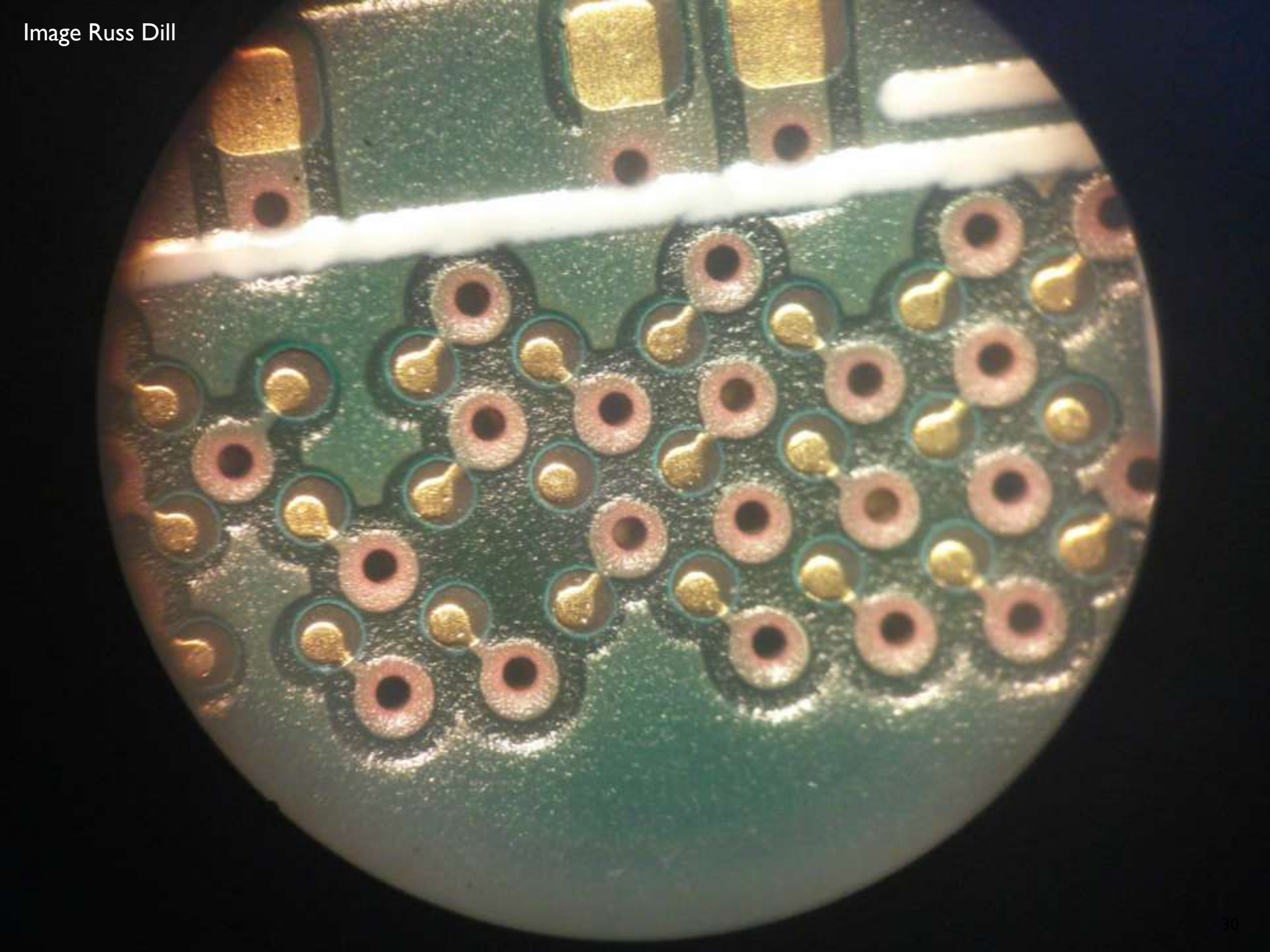
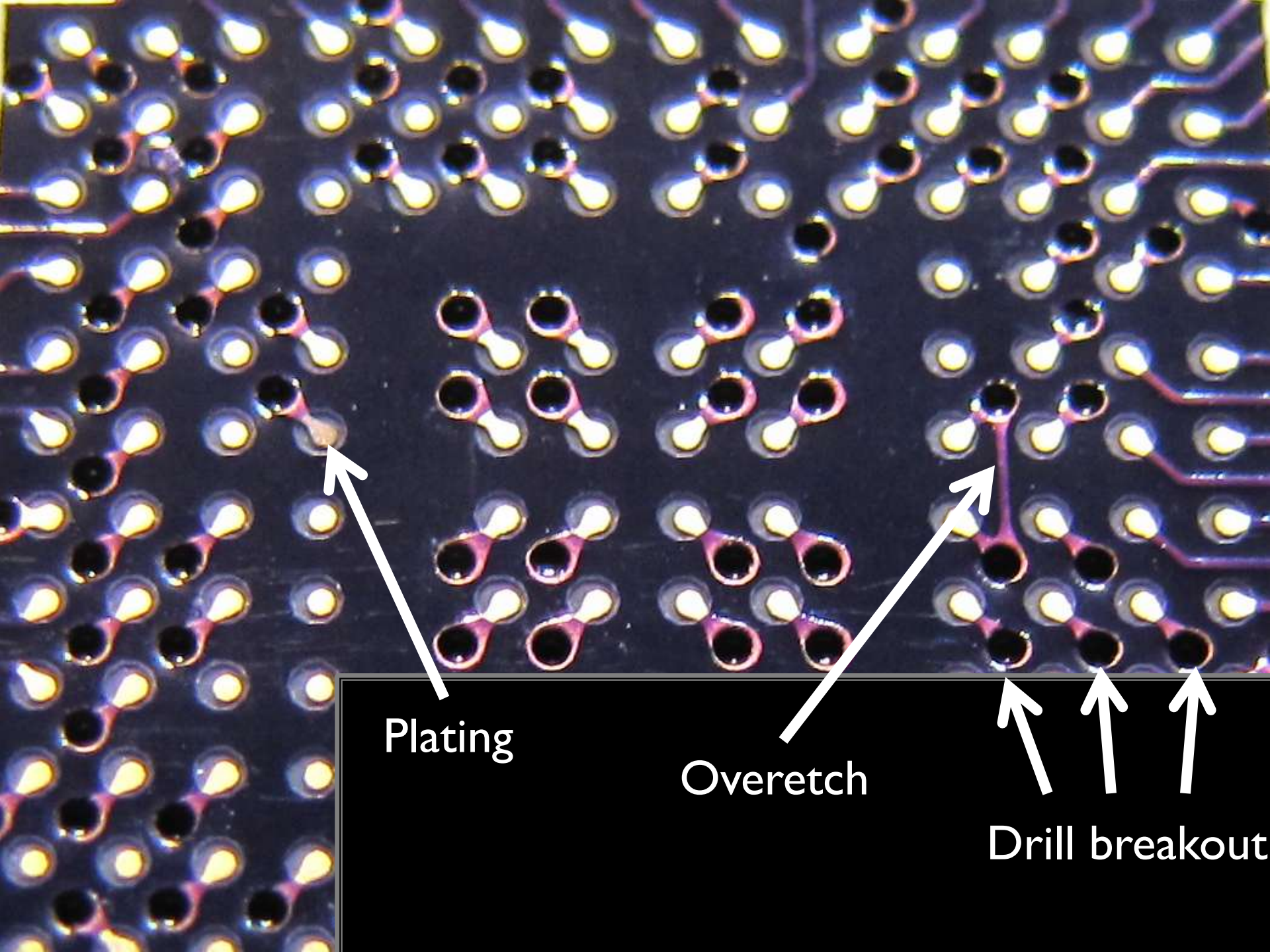


Image Russ Dill


Plating
Overetch
Drill breakout

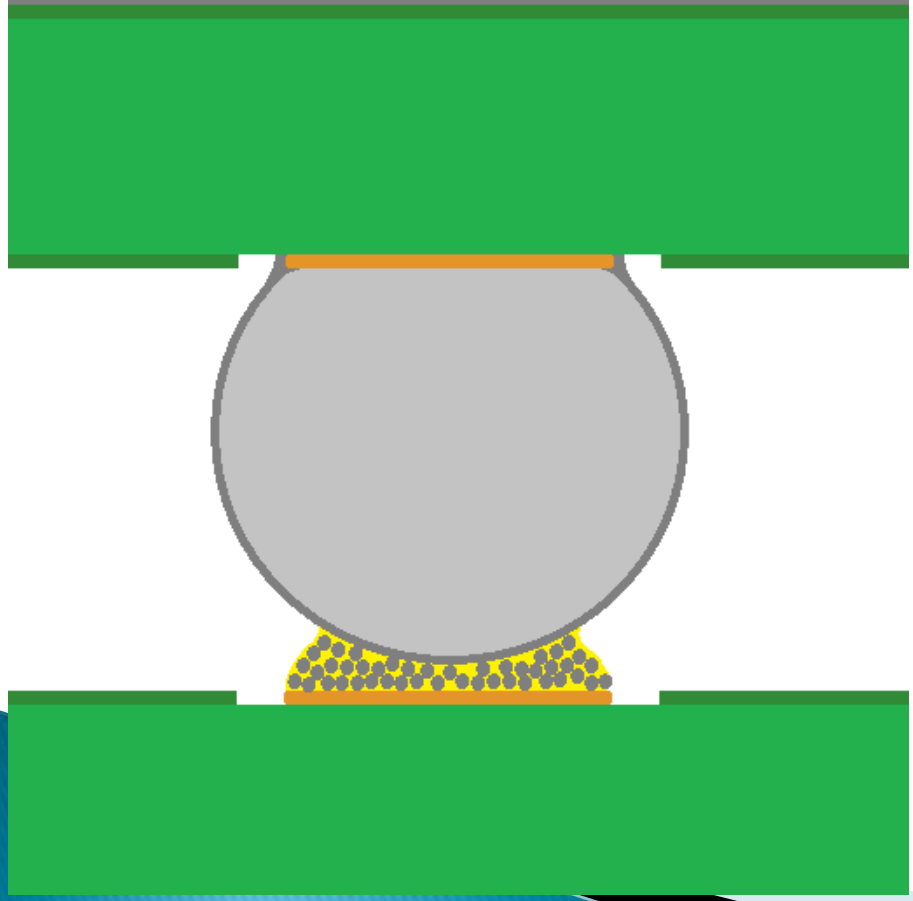
Assembly Overview

- Apply paste
- Place parts
- Reflow

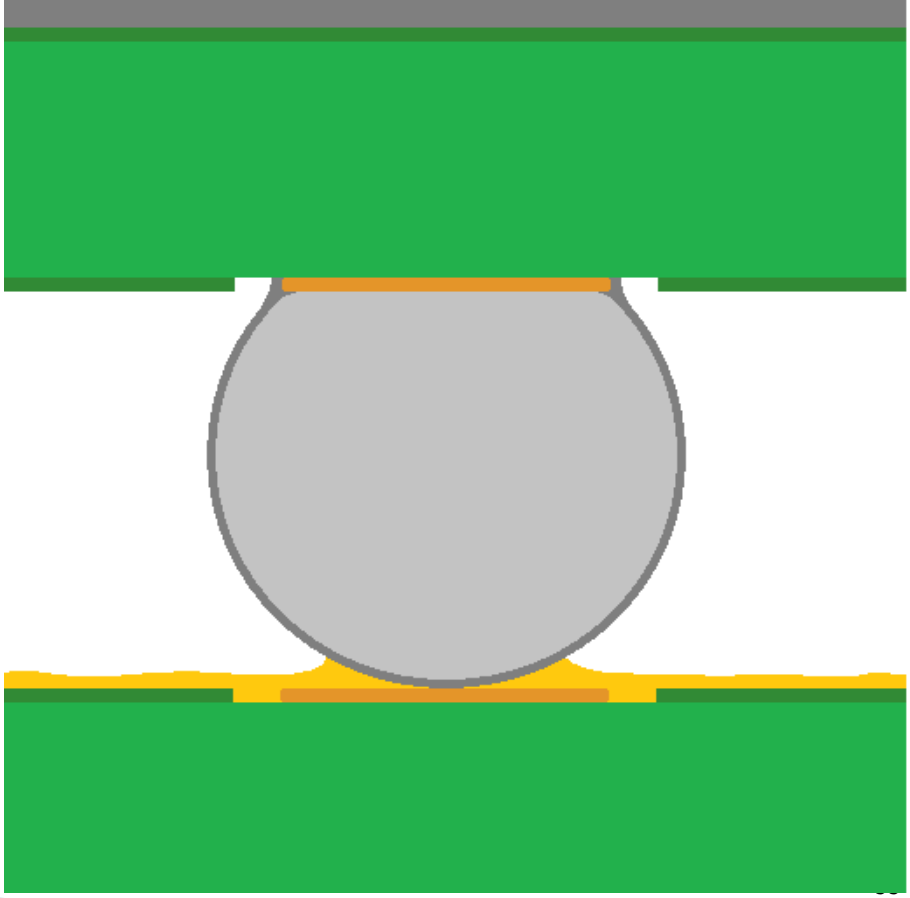
- Process is critical!!
- BGAs come preballed (leadfree)
- Either paste, or just flux the pcb

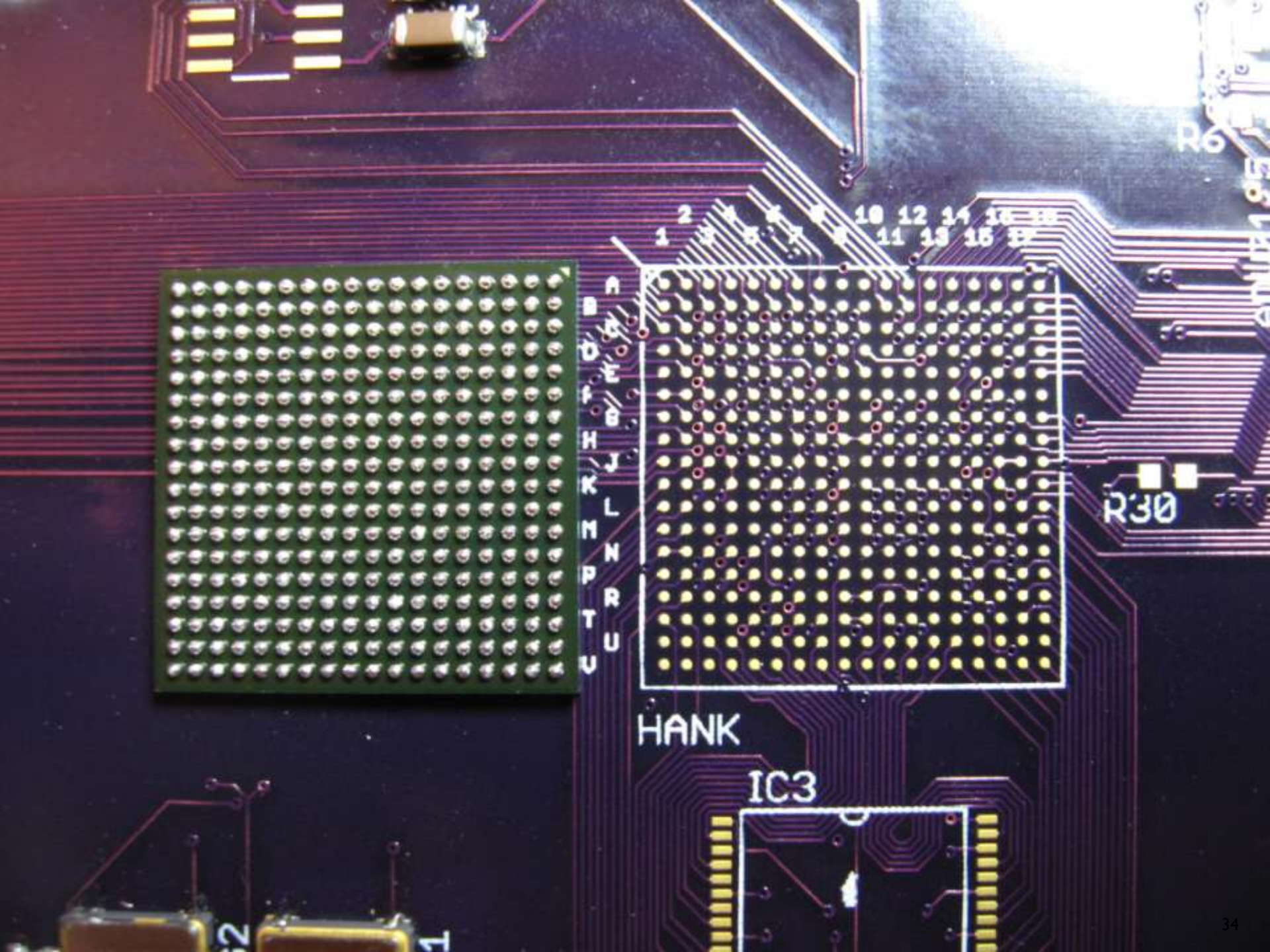
- Placement of BGA is super simple and easy
- Alignment: Copper best

Sitting on paste (recommended)



Sitting on flux (A+ planarity needed)




R6
R30
HANK
IC3

Alignment less critical

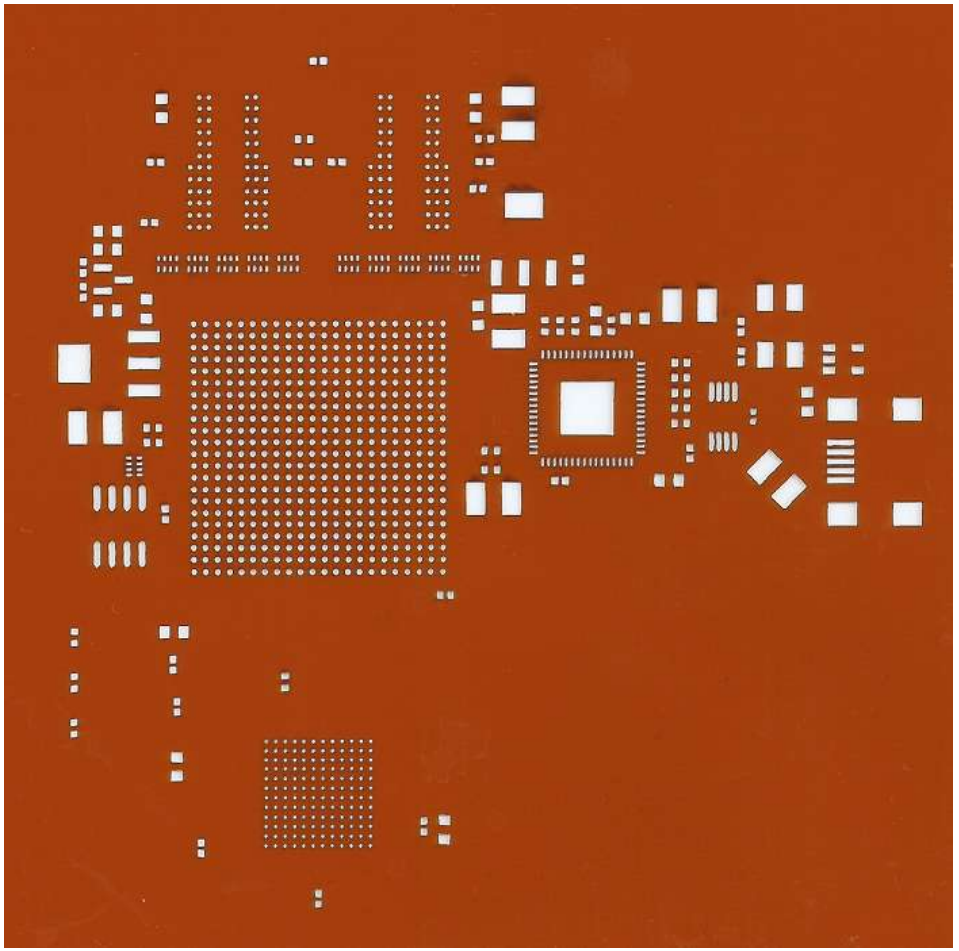
Solder paste

- Buy quality; cheap paste sucks
- BGAs come with leadfree balls
- Good for 6mos
- Store in fridge, don't freeze

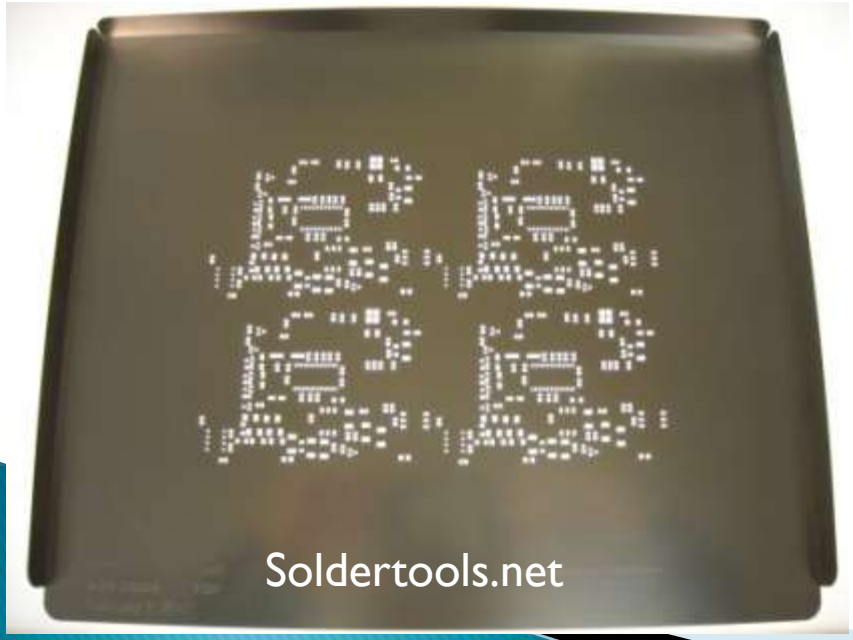
- I use SMD291SNL10-ND

Stencils

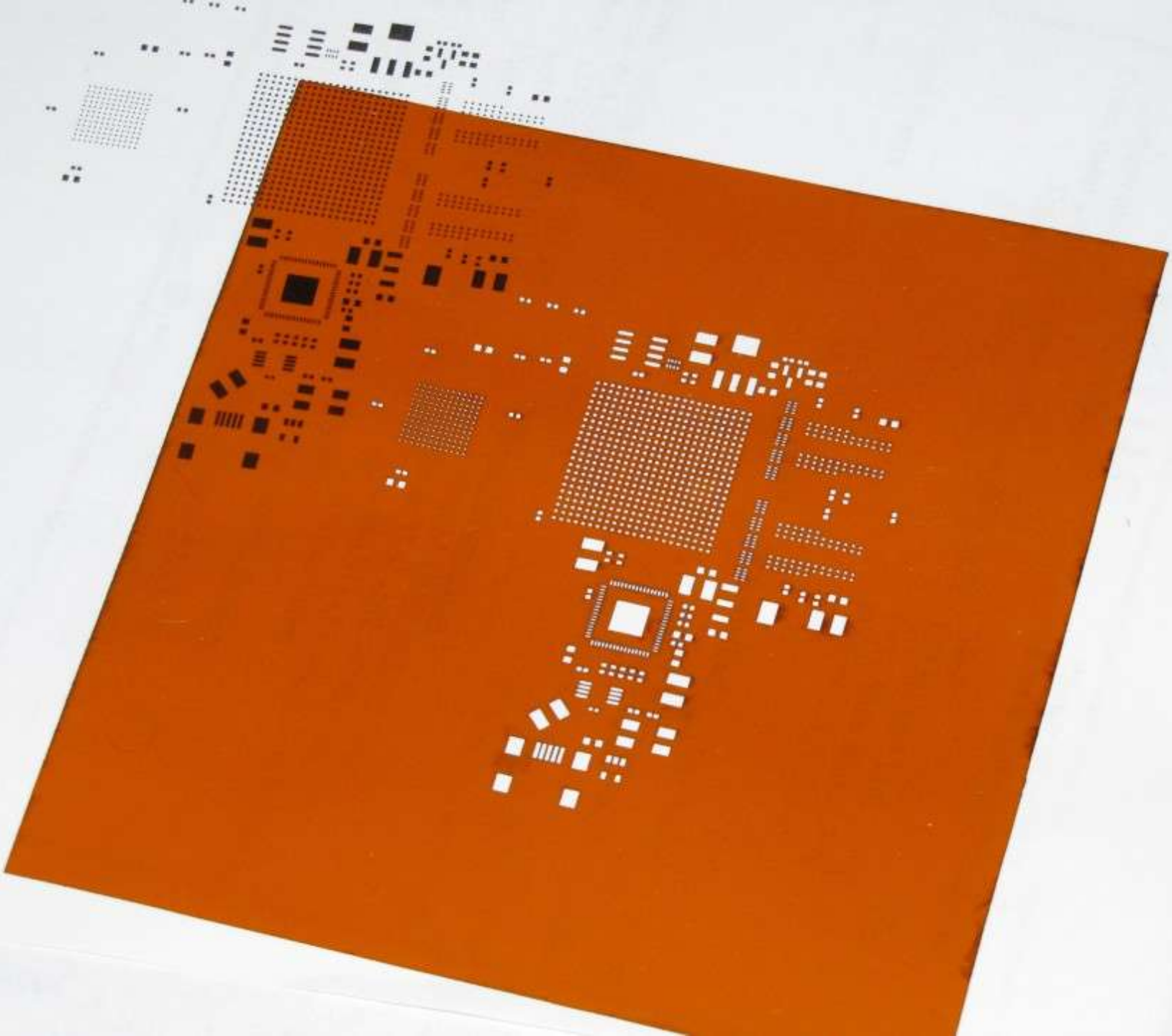
- Kapton (3,5mil)
- Stainless steel



Oshstencils.com
Ohararp.com



Soldertools.net



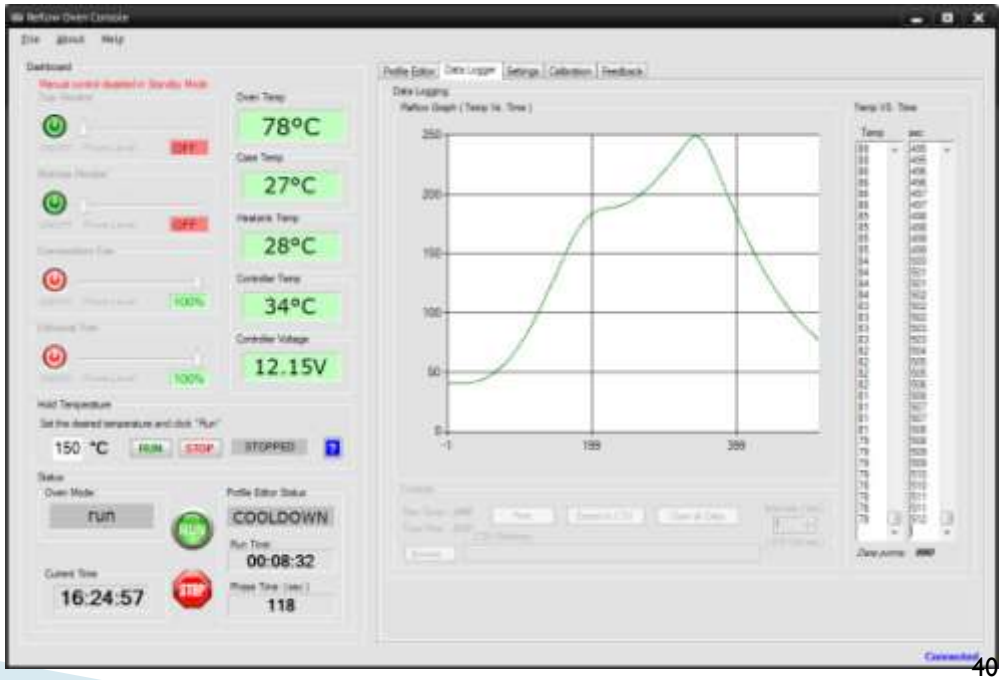
Reflow

- Heating paste past melting temp consistently and holding for a bit
- Exact timing/temps important for big runs
- “Good enough” works for prototypes
- Convection oven > skillet > hotair station

Images by Sparkfun

Reflow

- Hotair station only works for very small (<200 pin) monolithic BGA and QFNs
- Hotplate gives uneven heating, only 1 side
- Convection oven
  best bet



Reflow profiles

- Consult datasheets of the critical parts on PCB such as as main processor, large connector etc
- Basically all the same depending
- Leadfree and leaded are different of course
- Always do dry run with a dummy pcb of same thermal mass

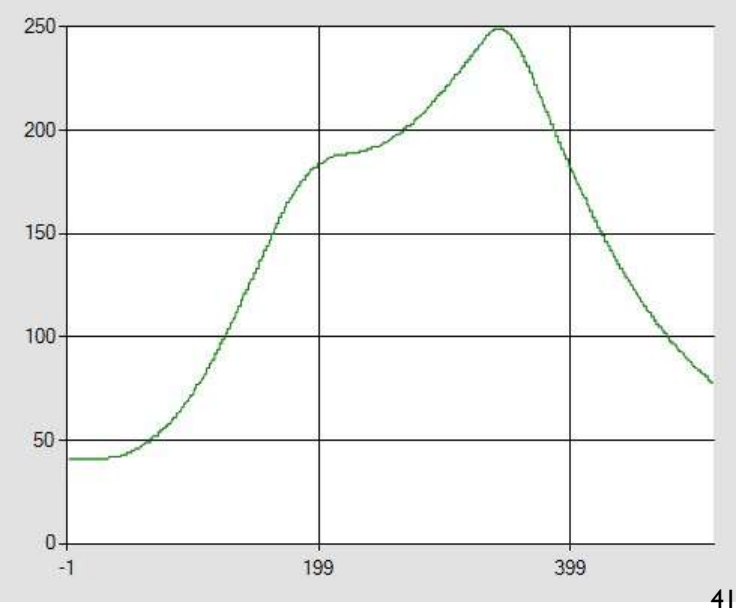
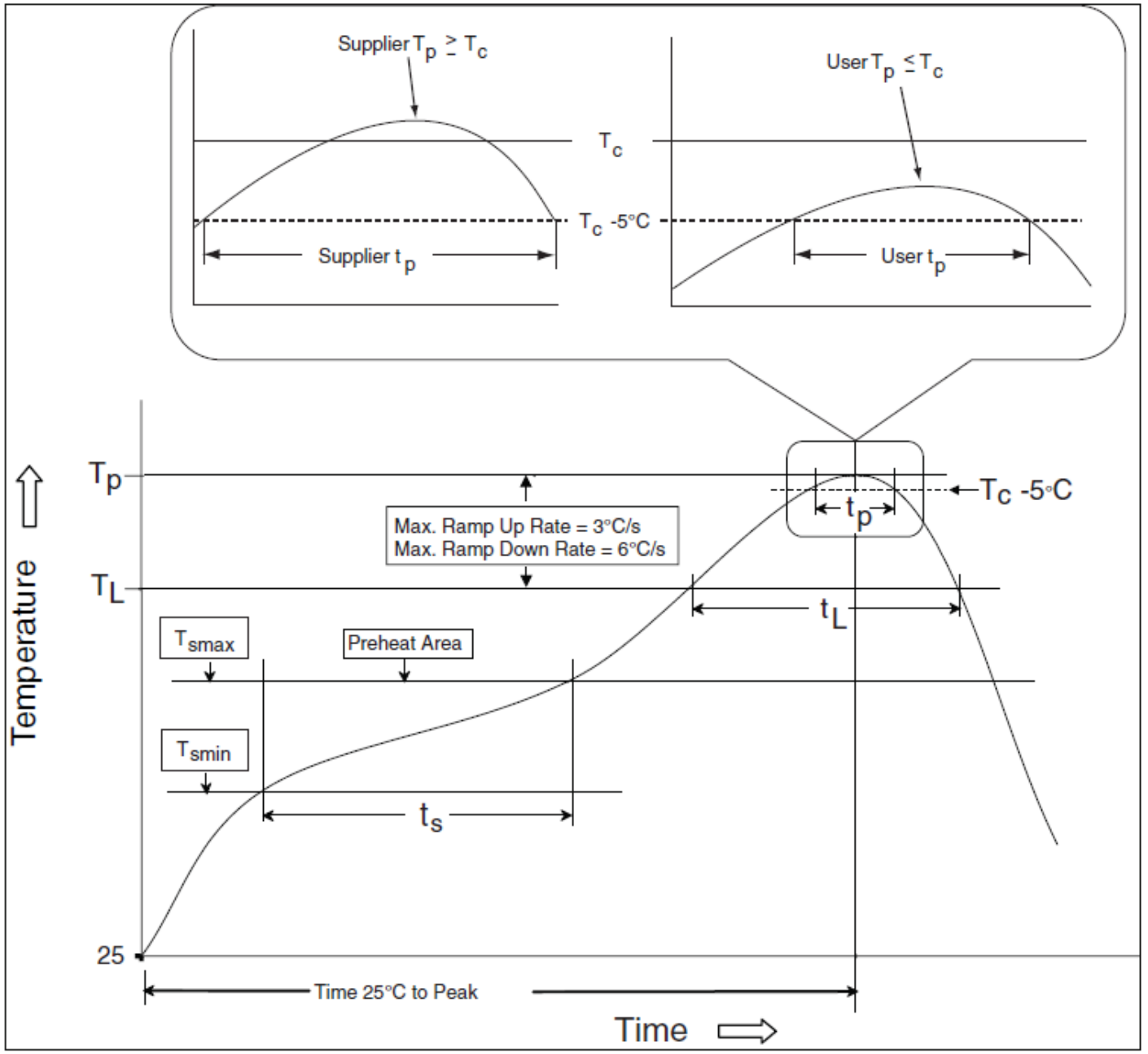
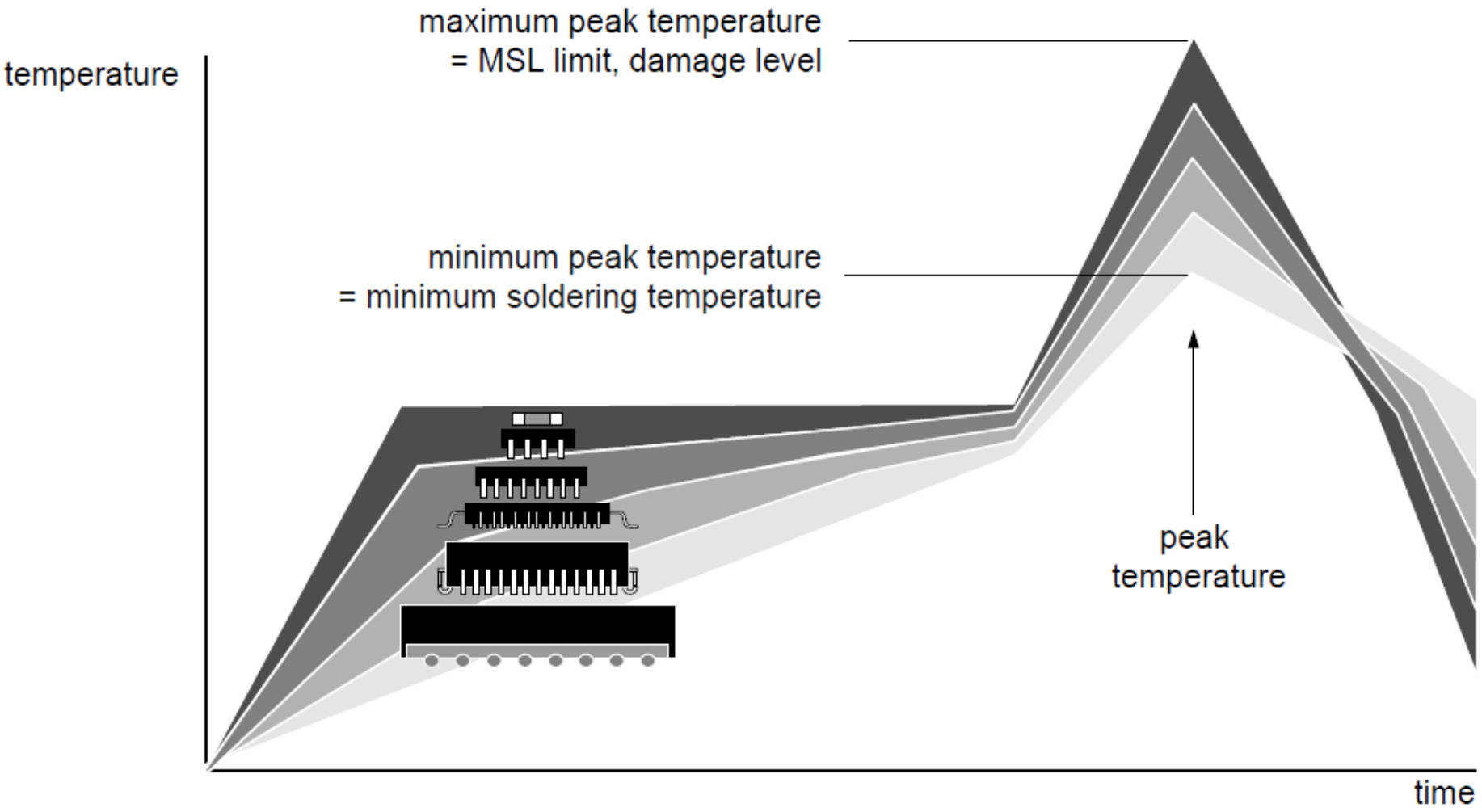


Figure 1. IR/Convection Reflow Profile (IPC/JEDEC J-STD-020D.1)





MSL: Moisture Sensitivity Level

Reflow profiles

- Preheat ramp speed
- Soak time (deprecated for RoHS)
- Time above liquidus
- Cooldown speed (degrees/second)

For protos, exact rates not critical!

<video>

<video>

<video>


P2Y7
1AA47
PW607
P2Y7
1AA47
PW607
MX
X113515
29LV400CTXEI-70G
3H701700AG
TAIWAN
MX
X113515
29LV400CTXEI-70G
3H701700AG
TAIWAN
ALTERA
EPM240GF100C5N
N CBM9M1037A
KOREA
VBM9M485113
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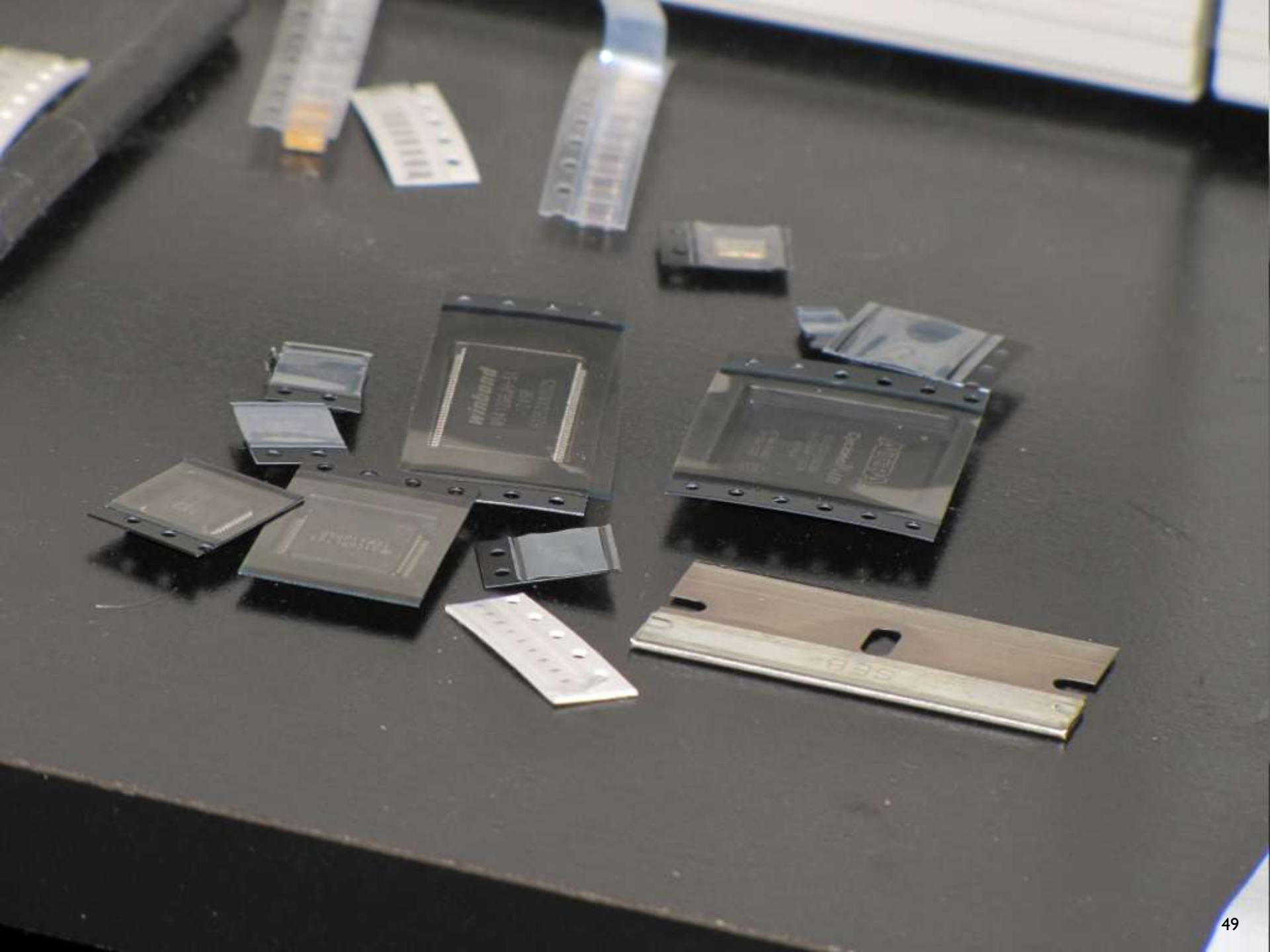
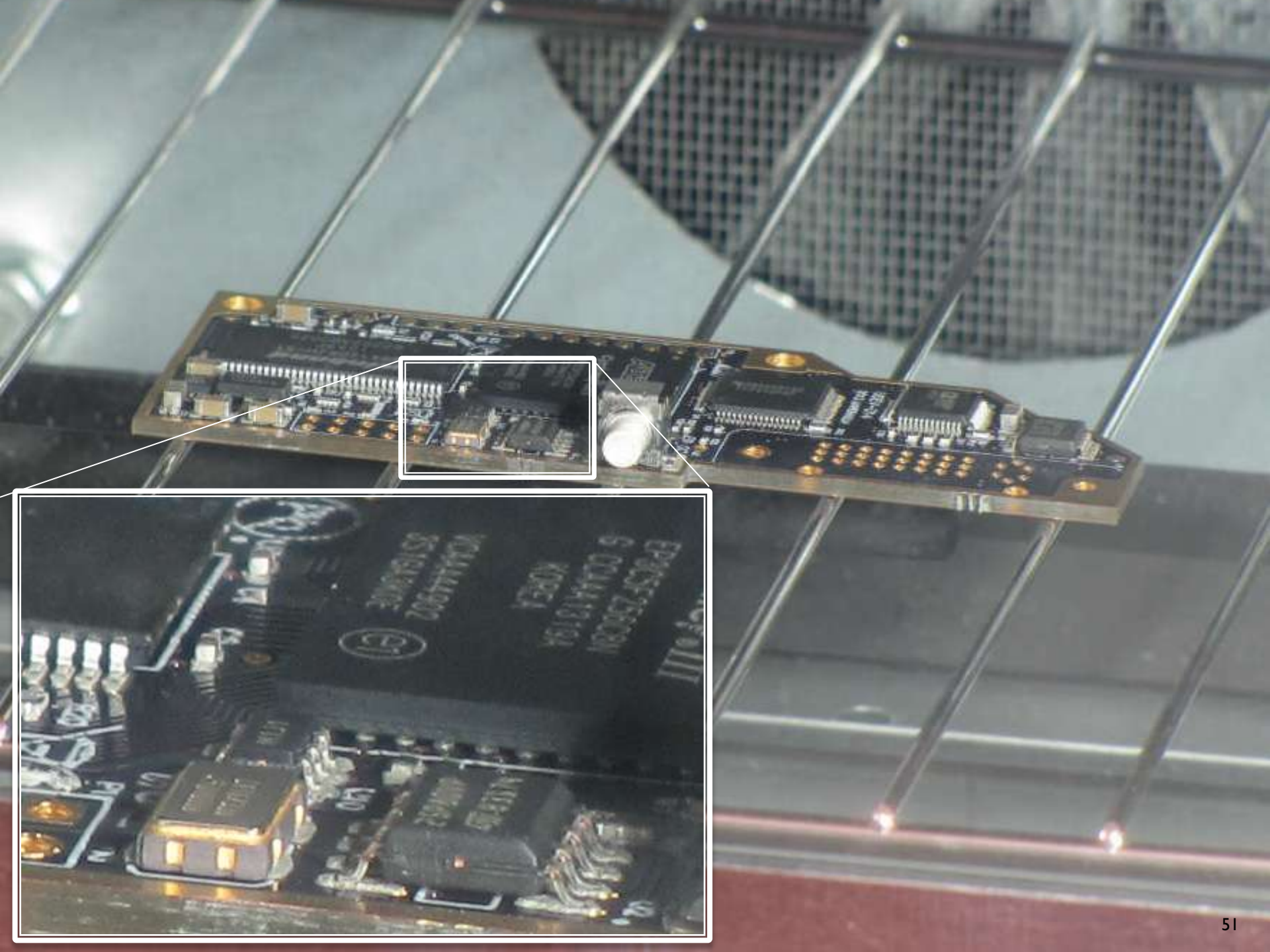
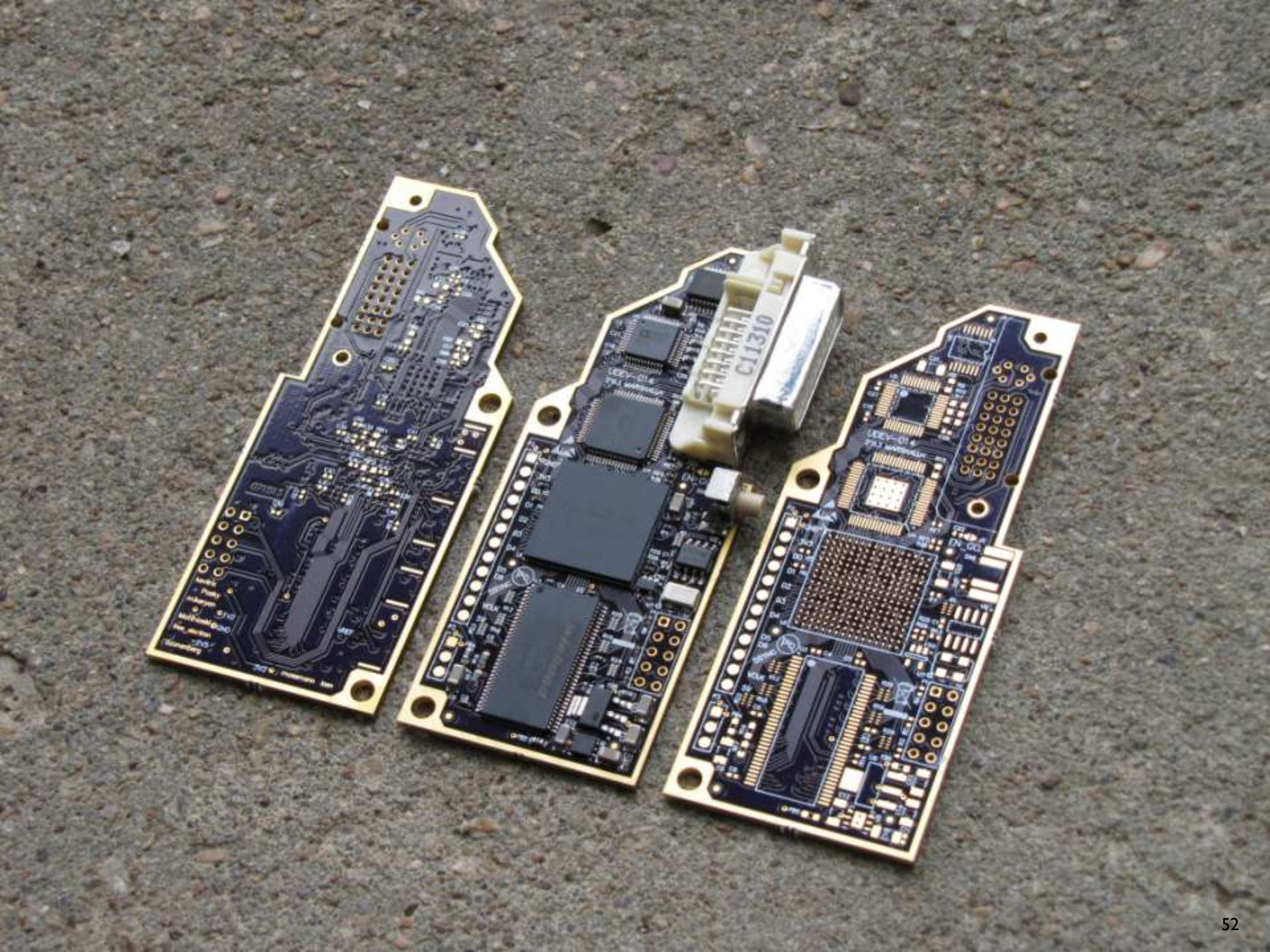


DANGER: HIGH VOLTAGE
PLASMA_PWR
APSU-001
ARGUS / IEE
PLASMA DISPLAY PSU
2012 MARSHALLH
KEVTRIS
CONT_PWR
12V DC
DANGER: HIGH VOLTAGE
DISPLAY PSU




C11310


Lattice
ECP3
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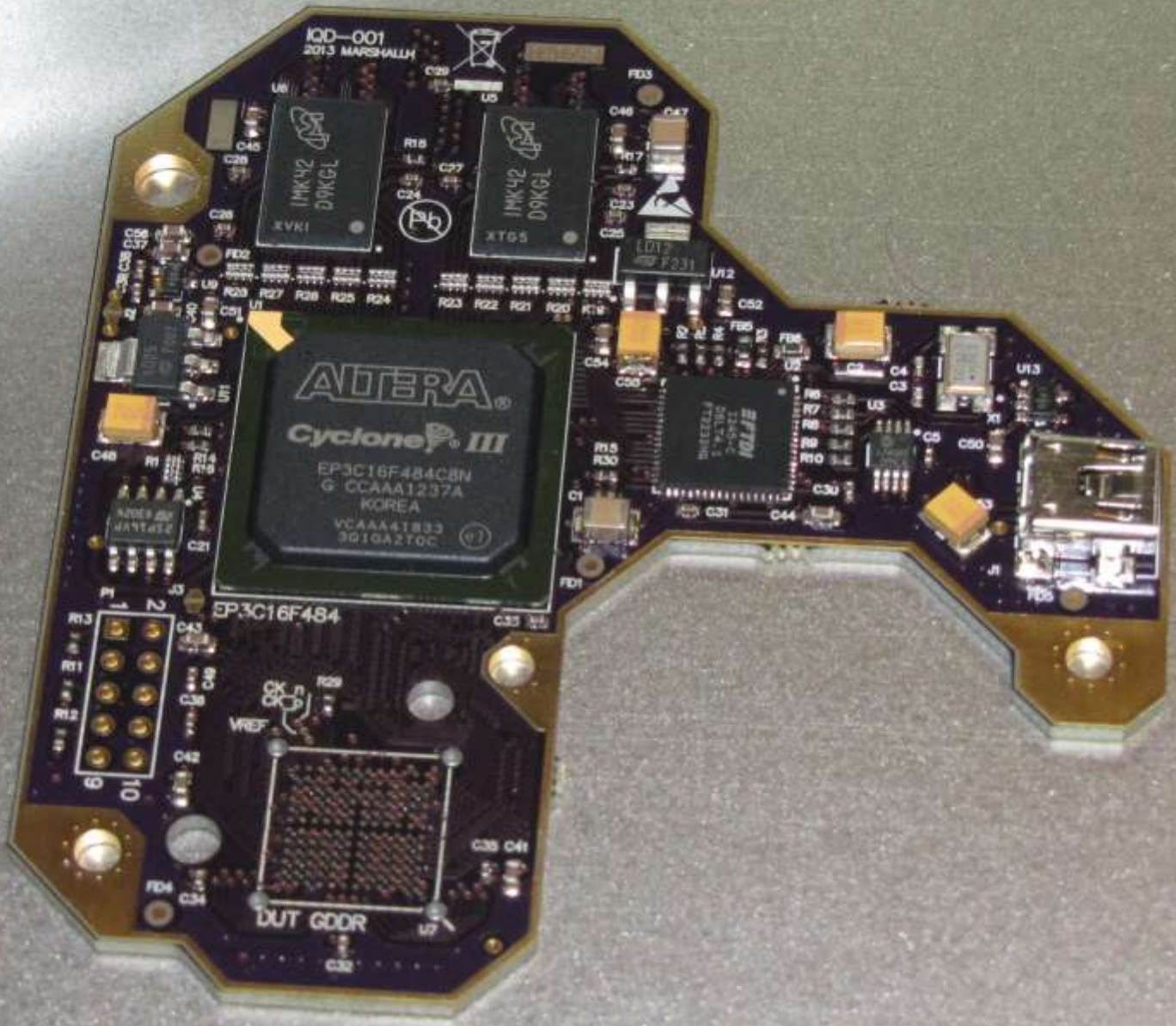
6FN484C
MADE IN CHINA
LSU3-001
VBUS
1V1
1V8
1V2
3V3
USER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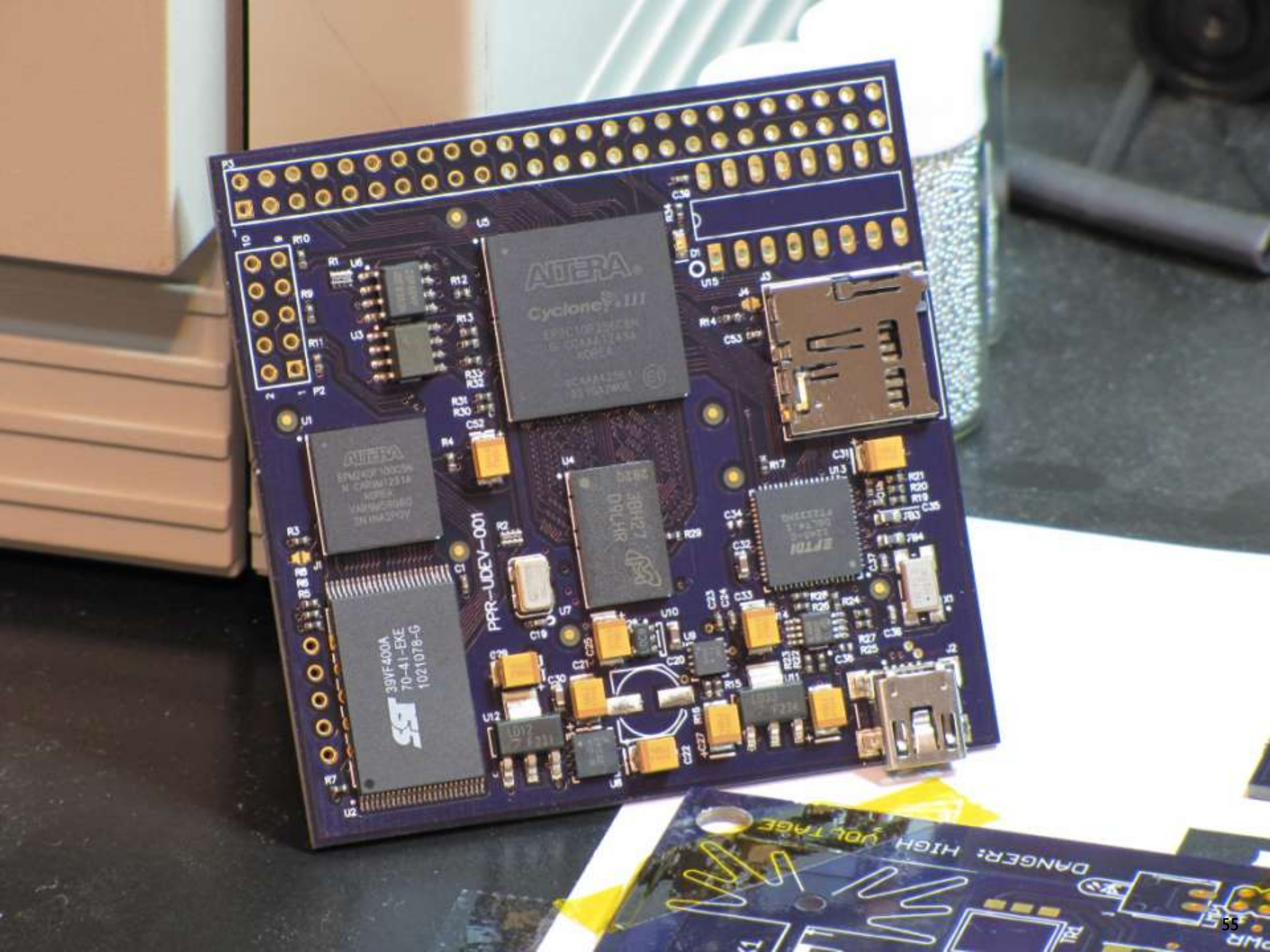
KOREA
EP3C16F484
DUT GDDR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Cyclone III
PPR-UDEV-001
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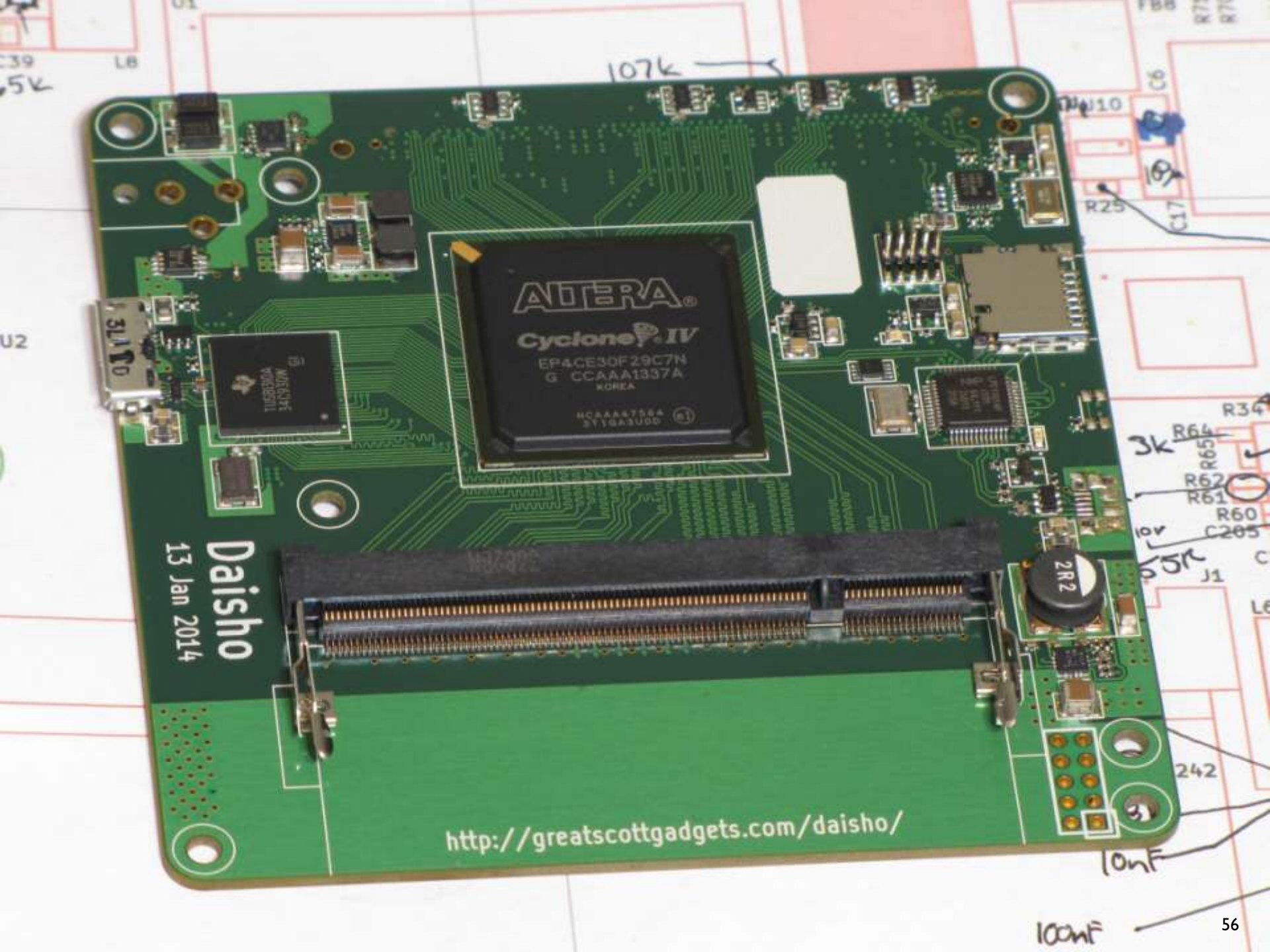
DANGER: HIGH VOLTAGE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Cyclone IV
EP4CE30F29C7N
G CCAAA1337A
KOREA
Daisho
13 Jan 2014
http://greatscottgadgets.com/daisho/

Failures

- Too long in soak will burn off flux
- Excessive voiding in solder balls
- Poor coplanarity of pads; bad wetting

- Other failures can manifest in the field:
  - Stress fractures caused by voids near joint
  - Dendritic growth/tin whisker
  - PCB failures such as via>plane shorts
  - Thermal cycling stress
  - Vibration/shock

Image azonenberg

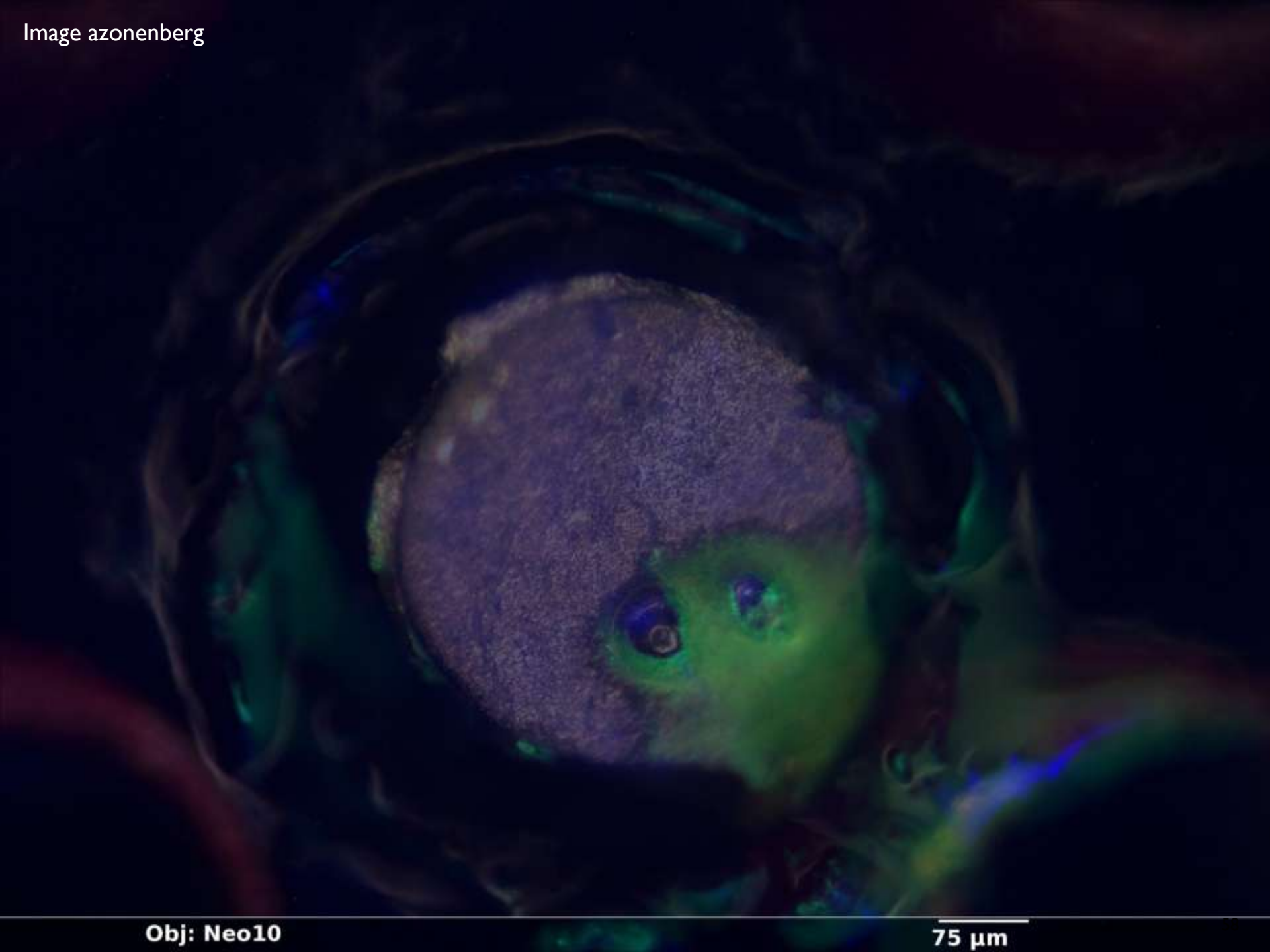
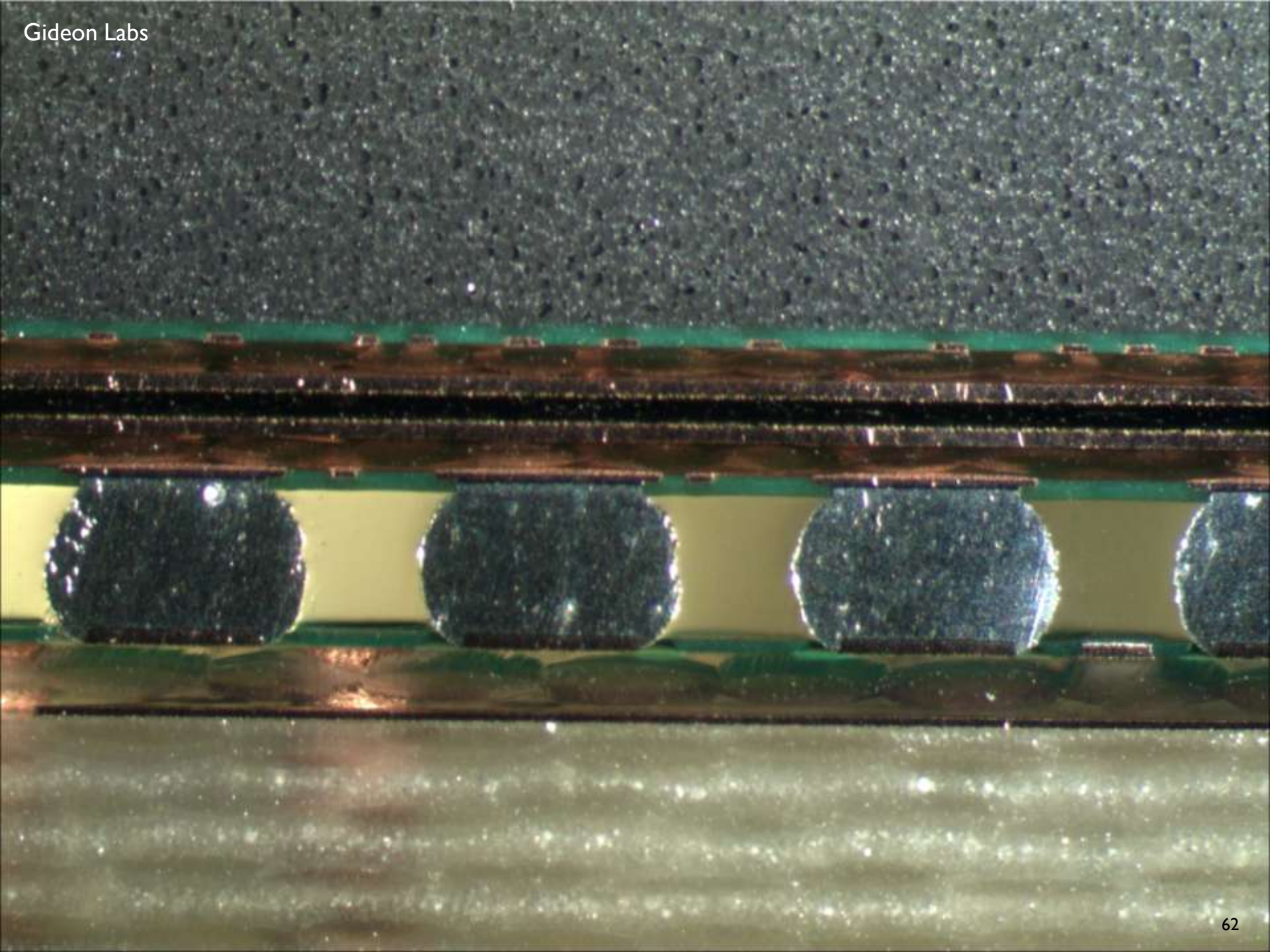
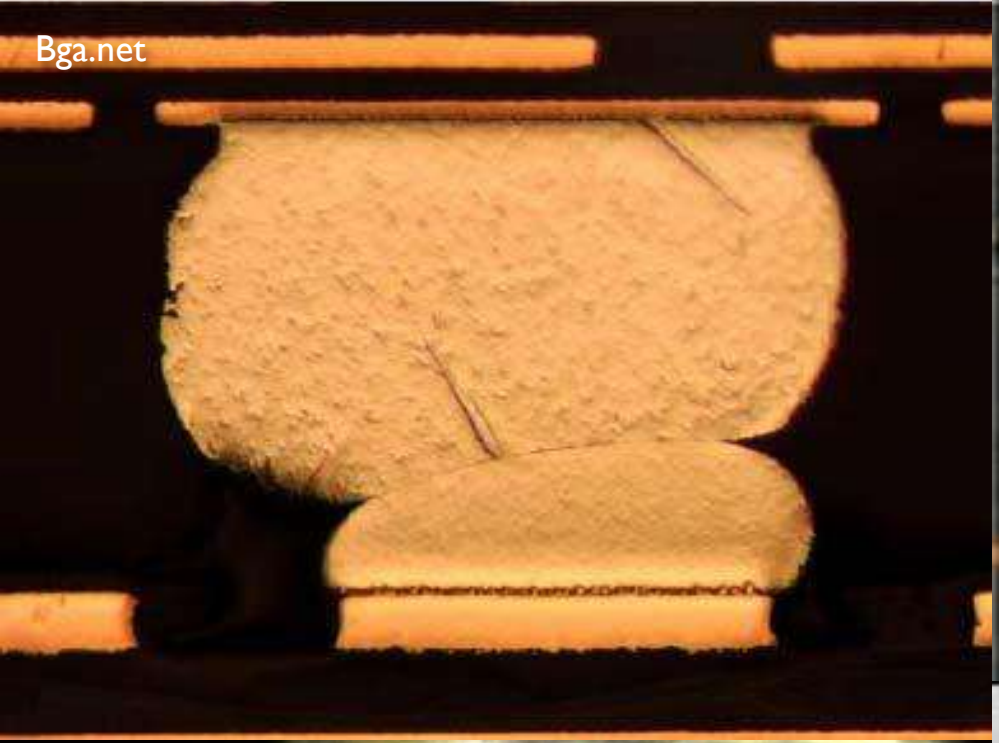


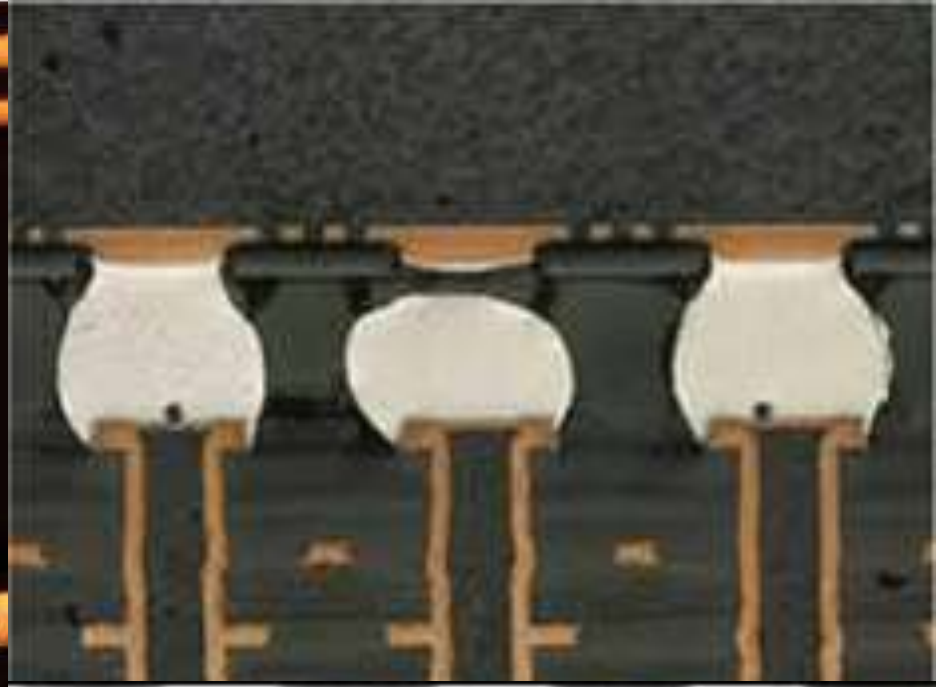
Image azonenberg

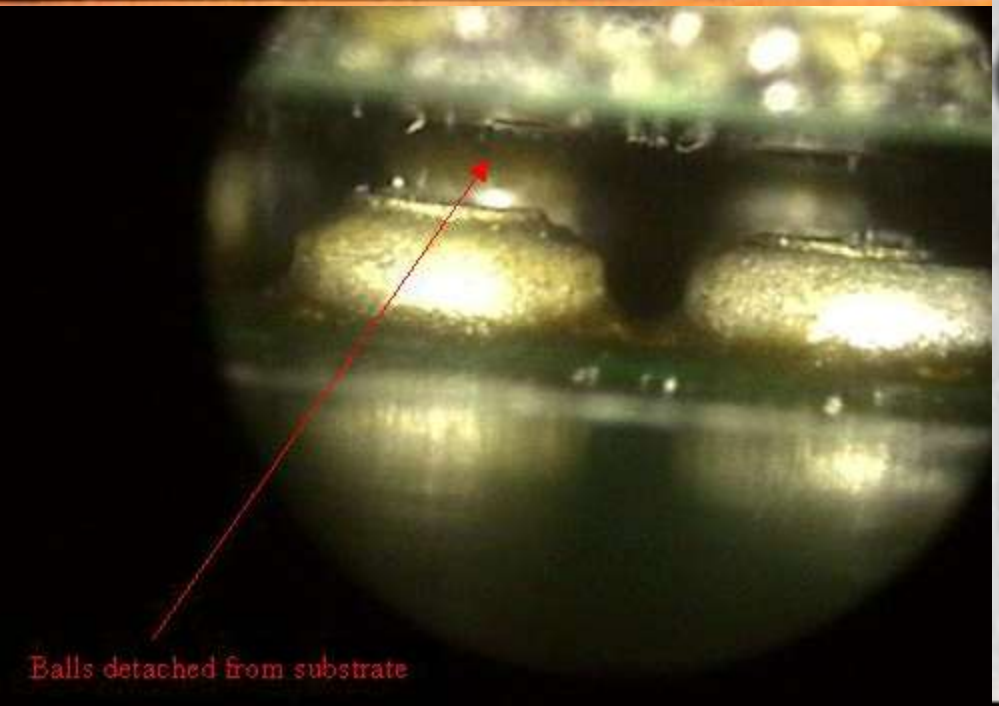

Image azonenberg
Obj: Neo10
75 µm

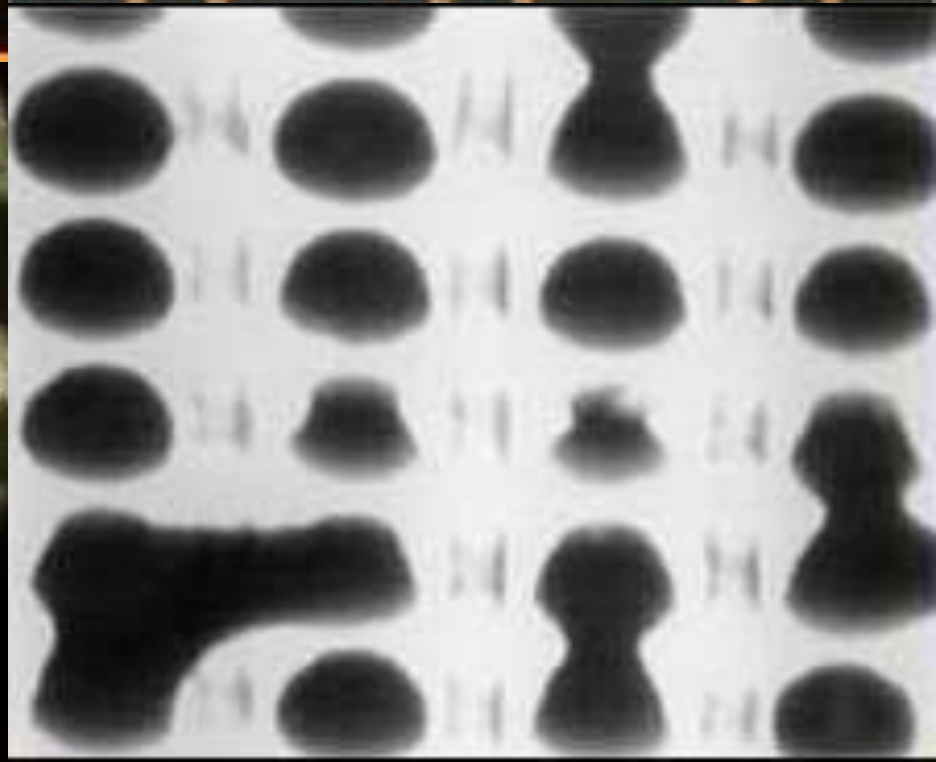

Image azonenberg
Obj: Neo5
100 µm


Gideon Labs


Bga.net




Balls detached from substrate

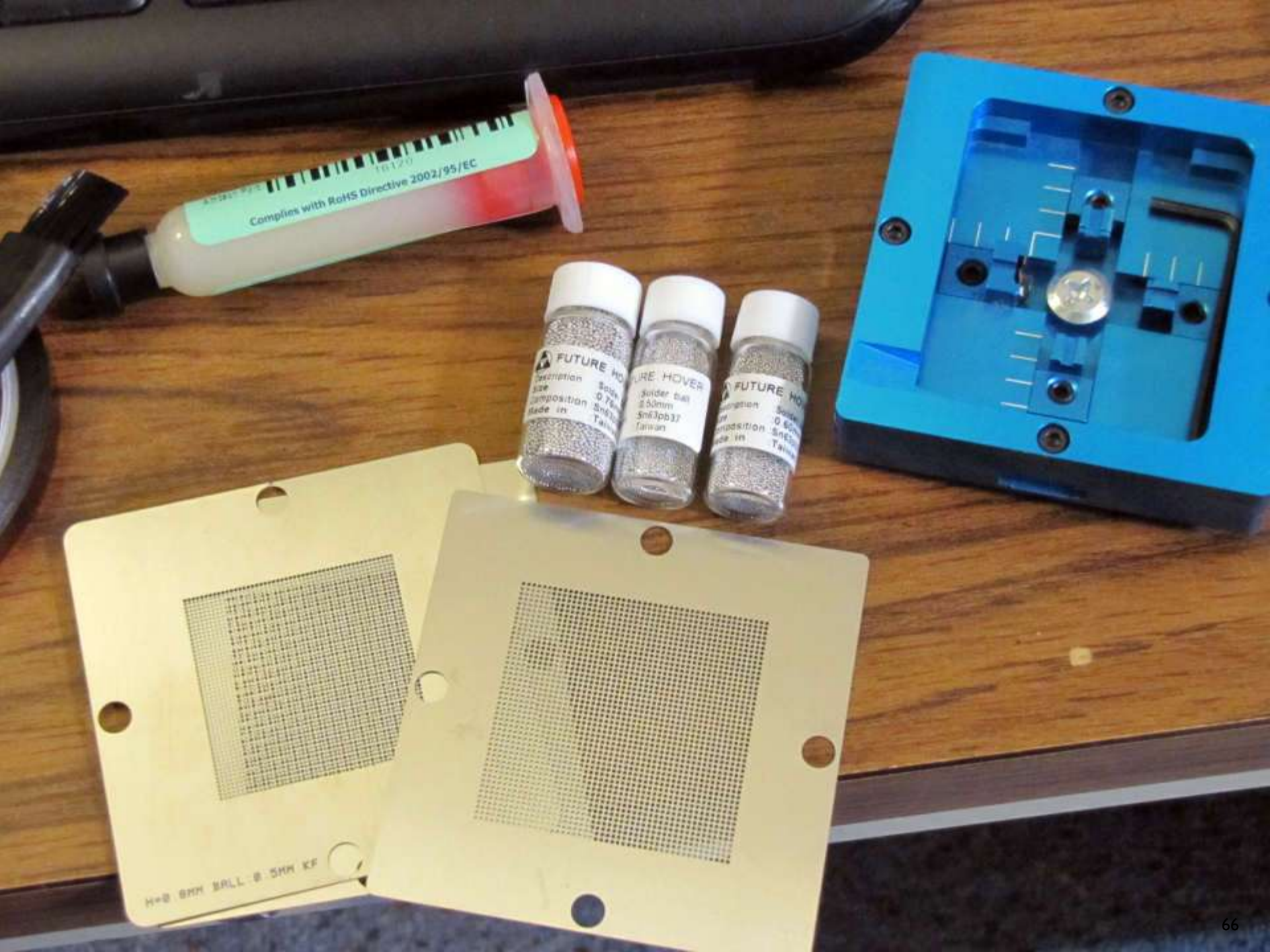


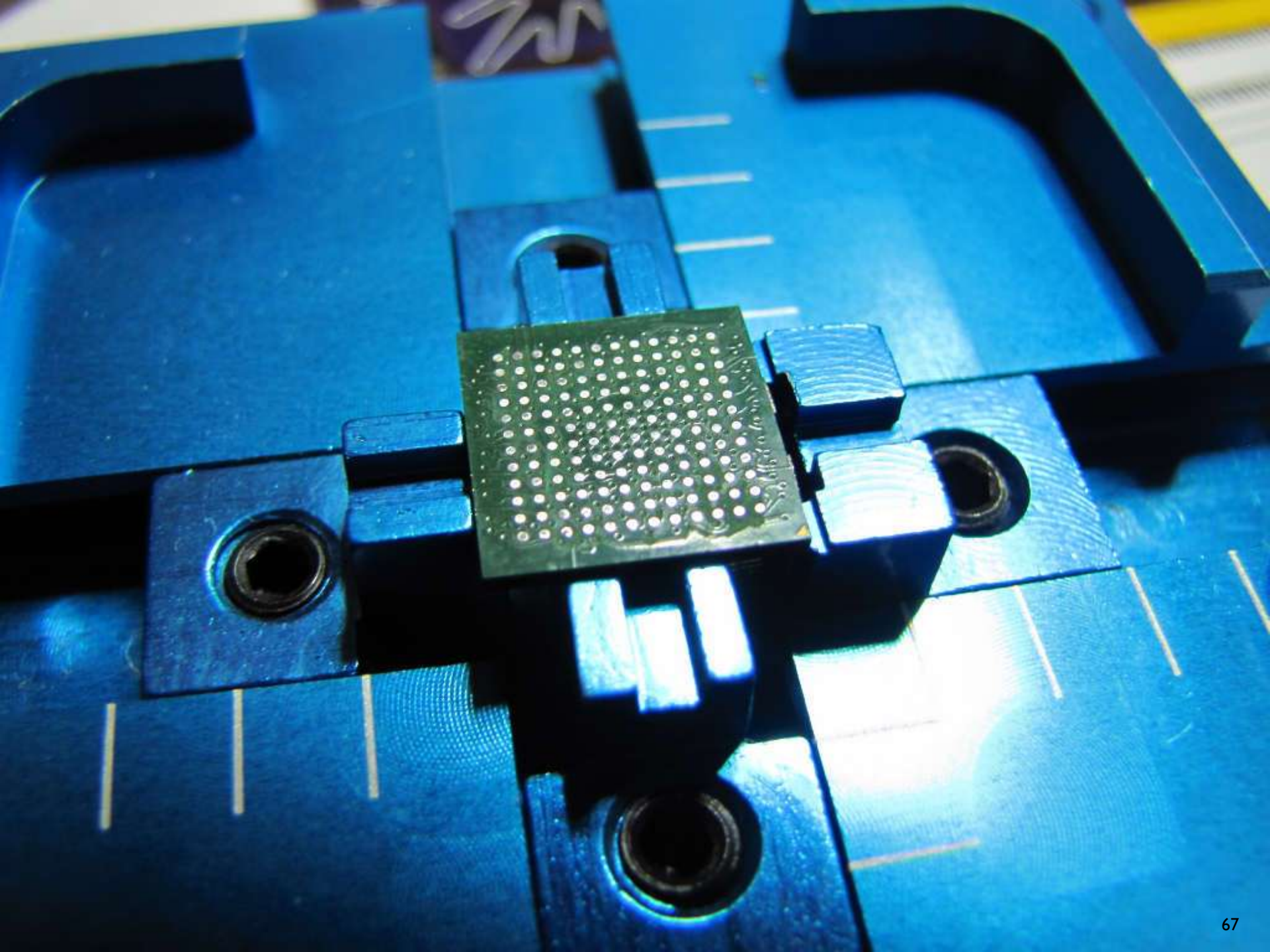
Rework

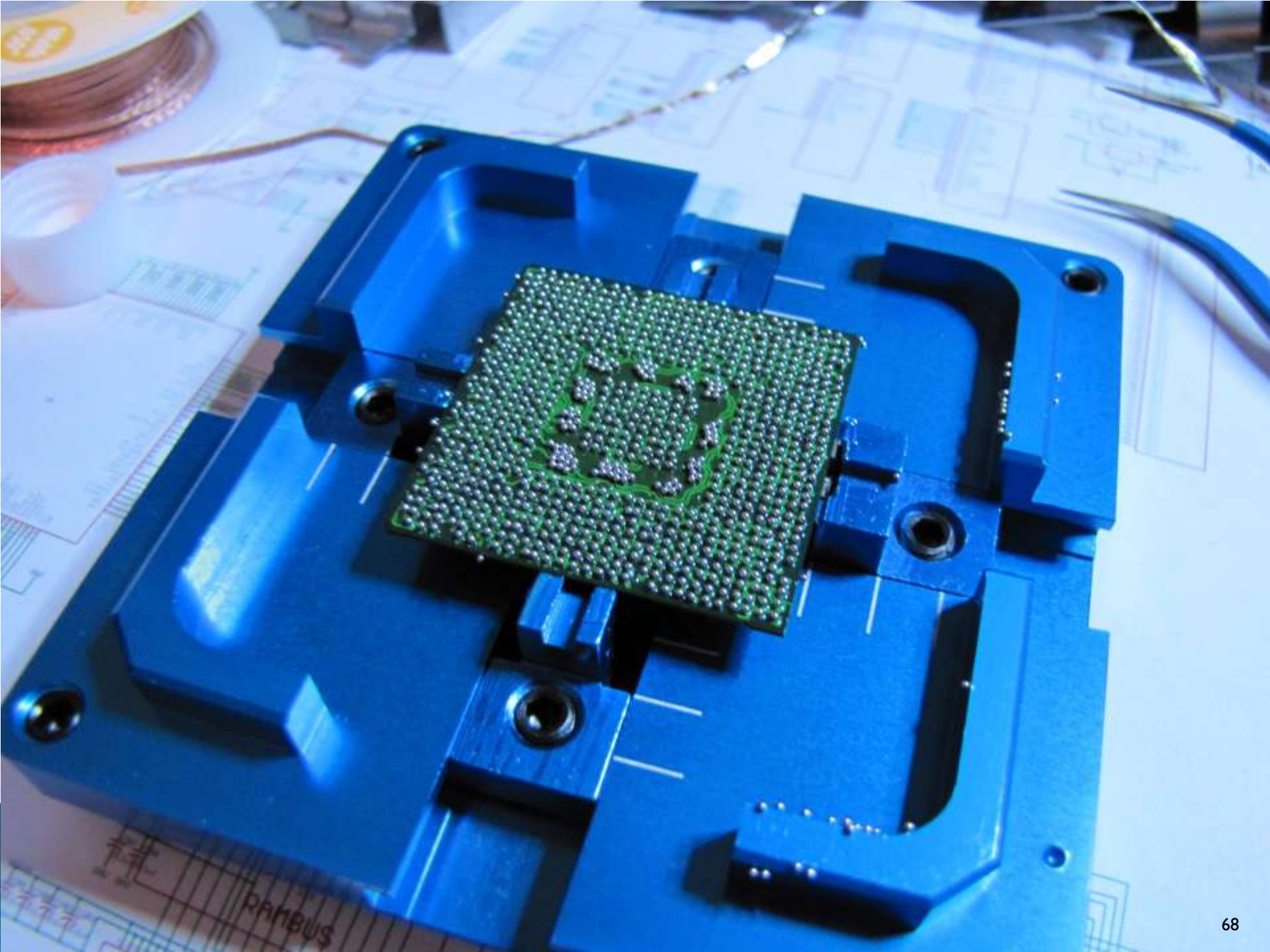
- Most BGAs only rated to withstand 3 cycles
- Preheating is necessary
- Hard to heat joints by blasting the top of the package

R&R

- Remove BGA
- Site PCB prep
  - Clean pcb lands, must be flat
  - 99% isopropyl
- Prep BGA
  - Remove all solder
  - Isopropyl
  - Chip away flux residue again
  - Flux and place balls
  - Reflow in oven only


Complies with RoHS Directive 2002/95/EC
FUTURE
Solder ball
0.50mm
Sn63pb37
Taiwan





Further reading

- Altera reflow guidelines
  http://www.altera.com/literature/an/an353.pdf
- Intel process guidelines
  http://www.intel.de/content/dam/www/public/us/en/documents/packaging-databooks/packaging-chapter-09-databook.pdf
- NXP reflow appnote
  http://www.nxp.com/documents/application_note/AN10365.pdf
- Breakout out very large devices
  http://www.pa.msu.edu/hep/atlas/l1calo/reference/other/mentor/mentorpaper_bga_breakouts_and_routing_52590.pdf

Questions

Thanks

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