CSCI 4974 / 6974
Hardware Reverse Engineering

Lecture 3: Depackaging
QUIZ 1: CMOS logic, packaging

- Quiz
- Discussion
Desoldering

- If the target device is on a PCB, remove it
- Standard desoldering techniques, mostly
- COB isn't soldered - special care needed! May need to process on the PCB
Depackaging

- We need to see the die to reverse it
- Some of the package (usually) has to come off!
- How much, and how we do it, varies
Bare die decap

- Destroys the entire package, wire bonds, etc
- May be able to probe, but awkward
- Generally used before destructive analysis
- Requires less skill
- Can sometimes rebond
Live decap

- Keep leadframe and bonds intact
- Requires more skill
- Typically used for probing
- Can be hard to get optics in close
- LWD obj helps
Non-selective techniques

- Mechanical cutting and grinding
- Laser ablation
- Thermal shock
- Good for removing bulk material quickly
- Can easily destroy sample if careless
Selective techniques

- Plasma / reactive ion etching (RIE)
- Wet chemical etching
Explosive decap

- Some of you have probably done this already!
- Abuse chip until it blows up
- Works on almost anything!
- Very easy
- Very risky
- Results unpredictable
Wet chemical etch

- Target: Plastic / epoxy packages
- Fuming HNO$_3$
- Concentrated H$_2$SO$_4$
- Solvents?
  - None have worked in my experience
Wet chemical etch

- All of these chemistries attack the epoxy. Glass particles wash off during cleans.
- Etching the glass is possible (HF) but...
  - Toxic and dangerous to handle
  - Non-selective: also eats glass on the die
  - So almost never used
Safety considerations

- Acids are corrosive. They'll “decap” your fingers or face if you give them a chance.
- Heated acids can fume, spatter, etc
- Flammable solvents
- Work in a fume hood
- Gloves, goggles, lab coat
Safety considerations

- Drop of hot H$_2$SO$_4$ on a paper towel
Bare die recovery: conc. $\text{H}_2\text{SO}_4$

- Materials cheap and common
- Optional: Cut/grind off extra plastic
- Drop packaged chip in acid, heat to ~200°C
- Takes several minutes
- Decant acid, filter die(s) out
- Clean with acetone
- Downside: Hard to see
Bare die recovery: conc. $\text{H}_2\text{SO}_4$

- **Dehydration**
  - $\text{H}_\ast\text{C}_\ast\text{O}_\ast \Rightarrow \ast\text{C} + \ast\text{H}_2\text{O}$
  - Acid does not react, just induces decomposition

- **Oxidation**
  - $\text{C} + 2\text{H}_2\text{SO}_4 \Rightarrow 2\text{H}_2\text{O} + \text{CO}_2 + 2\text{SO}_2$

- **Only some of the carbon is oxidized**
  - Lots of black sludge left over!
Bare die recovery: HNO$_3$

- Can use 65% or higher
- Drop packaged chip in, heat to 75-80°C
- Lower conc. attacks metal
- NO2 fumes from leadframe
- Clear solution, easy to see
Bare die recovery: $\text{HNO}_3$

- Oxidation only
  - $\text{Hydrocarbon} + \text{HNO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{NO}_2$
  - Attacks metals when dilute forming nitrate salts
    - $\text{Cu}_x\text{NO}_x$ from leadframe causes green tint
  - Does not release free carbon
Mechanical pre-milling

- Use precision milling machine
- Mill almost to die surface over logic area
- Leave small amount of package over bonds
- Finish off with acid or plasma
Laser pre-milling

- Same idea as mechanical
- Use pulsed high-power laser
- CW lasers just melt :(
Live decap: $\text{HNO}_3$

- Stronger acid is better, weak eats leadframes
- 70% can work with care, fuming is better
Live decap: $\text{HNO}_3$

- Pre-drilled PDIP
Live decap: $\text{HNO}_3$

- Heat package to 125C (chip heats acid)
- Drop acid in cavity
Live decap: $\text{HNO}_3$

- Rinse with acetone between drops
Live decap: $\text{HNO}_3$

- Do not allow acid to dry up on sample
- Water or dilute acid will damage leadframe
- Allow solvent to evaporate before next drop
- $\text{HNO}_3 + \text{alcohol} = \text{BOOM}. \text{Avoid at all cost}$. 
- $\text{HNO}_3 + \text{acetone}$ is exothermic. Need lots of solvent to keep temps under control
- Indirect blow-dry after final clean
Live decap: conc. $\text{H}_2\text{SO}_4$

- Roughly same process as nitric live decap
- Common, cheap materials
- Run much hotter, around 225°C
- Sulfuric is much more viscous than nitric
  - Harder to clean off sample
- Acid *must* be completely removed before returning to heat - dilute acid bubbles epoxy
Live decap: conc. $\text{H}_2\text{SO}_4$

- If you see this, old acid wasn't removed fully
- Too late, chip is probably a writeoff
Successful live decap
Dirty decap
Plasma etching

- Mostly used by professional shops
- Oxygen plasma eats organics
- Periodically remove from etch chamber and remove glass particles
Thermal shock

- Target: CERDIP
- Somewhat risky to die
- Cheap and easy
Thermal shock

- Heat up with torch for 5-10 sec
- Splash with water (do not submerge)
- Break parts apart with pliers
Thermal shock
Grinding

- Target: Metal-can packages or metal lids
- Makes a big mess
- Low skill
- Super cheap
“Can opener”

- Target: Metal-can packages or metal lids
- Requires special equipment and more skill
- Does not leave particles on die
Soldered lids

- Heat up package with heat gun
- Pick lid off with tweezers
- Avoid dropping solder on die
Glass lids

- Same process as soldered lids, but usually requires a lot more heat (torch)
- Can also work on CERDIPs held together with low-melt glass
Cleaning

- Many decap processes leave junk on die
- Can cause artifacts when delayering
- Interferes with imaging
Mechanical swabbing

- Gently brush die with corner of acetone-soaked lab wipe
- Must use lint-free to avoid contaminating die
- Lint-free microfiber swabs also work
- Risk of scratching sample or knocking bond wires loose
Overly aggressive swabbing
Spray cleaning

- Fill large syringe with acetone
- Attach very fine blunt-tip needle
- Spray particles off die
- Wash bottles are less precise and may be lower pressure
Ultrasonic cleaning

- Can use water, detergent, or solvent
- If using detergent, must be lab-grade (no moisturizers/perfumes etc)
- May be too strong - often destroys bonds
- Usually safe for bare dies
Acid cleaning

- Sometimes a little more time in clean decap acid will remove organic residues.
- Must be fresh acid - otherwise no point!
Solvent practices

- Do not allow dirty solvent to dry on die
- Wash off with clean solvent
- Blow dry
- Avoid technical grade solvents/duster sprays - lots of impurities
Bond wire removal

- For bare-die decaps, bond wires are a nuisance
- Need to remove to get flat surface for polishing
Wire Plucking

- Target: All metals
- Grab wire with tweezers and yank
- Only ~3 grams force required
- Use care not to scratch die surface
- May rip metal off bond pad
Ultrasound

- Target: All metals
- Ultrasonic cleaning sometimes damages bond wires anyway
- If you want them gone, just turn up the juice!
- Risk of damage to die is similar to plucking
Hydrochloric acid

- Target: All metals
- Bond pads are copper or aluminum
- If you don't need them preserved, etch the metal out from around the wire
- Destroys bond pads, acid may also damage adjacent wires on die if there are any cracks
Solder

- Target: Gold bonds on Al pads
- Au is soluble in molten Pb
- Trim off as much wire as possible beforehand
- Drag a bead of lead-based solder back and forth over the bonds until they dissolve
- Solder will not harm Al bond pads, but may stick to (or dissolve) Cu
Questions?

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