EE 527 MICROFABRICATION

Lecture 22

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WET ETCHING OF ALUMINUM (AL)

- HCl : H_2O @ 1:4
- H_3PO_4 : HNO_3 : H_2O @ 74:7:19 gives a very rapid etch rate
- Almost any of the strong acids with an oxidizer will etch aluminum:
  - H_2SO_4
  - HNO_3
  - HCl
  - H_3PO_4
- The trick is usually diluting the acid / oxidizer mixture down to a point to where it can be controllable.
- If the aluminum has a thick skin of Al_2O_3, this may first have to be removed using an HF-based etchant.

WET ETCHING OF GOLD (AU)

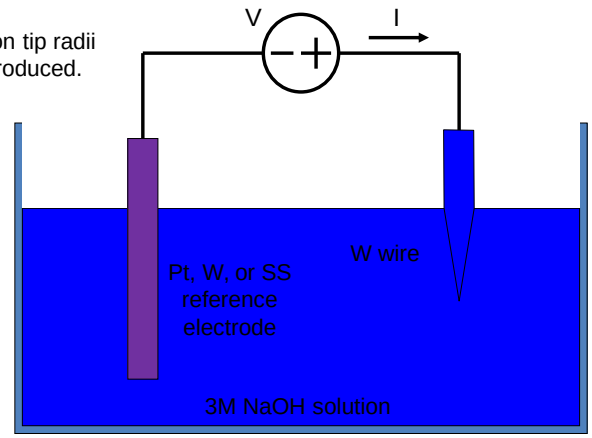
- HCl : HNO_3 @ 3:1 (Aqua regia)
- Gold Etch (TFA):
  - KI : I_2 : H_2O @ 1.3 g : 65 g : 100 mL @ room temperature (2-0-0)
  - Etch solution is nearly black and impossible to see wafer once submerged.
  - Also etches most compound semiconductors @ ~1.0-2.0 μm/min

HYDROXIDE ETCHING OF W PROBE TIPS

- Tungsten (W) probe tips are often used for wafer and die probing as well as for STM/AFM applications.
- Very sharp tips are needed – sharper than what can be achieved through standard mechanical machining processes.
- Concentrated (1-3 M) KOH or NaOH can be used to electrolytically etch W. A W wire is positively biased as the anode and the etch proceeds as:
- Anode reaction: $W(s) + 6OH^- \rightarrow WO_3(s) + 6e^- + 3H_2O$
  $WO_3(s) + 2OH^- \rightarrow WO_4^{2-}(aq) + H_2O$
- Cathode reaction: $6H_2O + 6e^- \rightarrow 3H_2(g) + 6OH^-$
- Typically, +4 to +12 Volts is applied to the W anode.
- Higher voltages and higher concentrations produce faster etch rates and better tip results.

HYDROXIDE ETCHING OF LARGE TIPS – SUCCESSIVE DIPS

Submicron tip radii can be produced.



The tip etches faster because the electric current density is concentrated there, and the tip is also in the solution longer.

TECHNIQUES FOR REPRODUCIBLE WET ETCHES

- Design the etch rate for a controllable time period, e.g. several minutes, so that dip and extract times are comparatively short. Dilute the etch if necessary.
- Agitate gently using N_2 bubblers, when available.
- Use a timer – don't guess.
- Use fresh chemicals.
- Control the temperature of the etch bath.
- Use a thermometer – don't guess.
- Never mix different substrates within the same etch bath.
- Always etch the same thing in the same equipment with the same chemicals under the same conditions!

ETCH TUNING TECHNIQUES

- For three-part etches (acid/base – oxidizer – dilutent):
  - Adjust the overall etch rate through the amount of dilutent while keeping the acid/base – oxidizer ratio constant.
  - Adjust the surface finish of the etch through the acid/base – oxidizer ratio while keeping the dilutent fraction constant.
- If necessary, use two etches in sequence:
  - 1. Roughing etch with a high rate to rapidly remove material.
  - 2. Finishing etch with a slower etch rate and more polishing action to produce a higher quality final surface.
- Adjust the etch temperature to balance the reactant transport against the surface reaction rate.
  - Polishing etches tend to be transport-limited, usually by diffusion.
  - Roughing etches tent to be surface reaction rate-limited.

ANISOTROPIC WET ETCHING (11.3 & CHAPTER 20)

SILICON CRYSTAL STRUCTURE

- Silicon atoms in a crystal lattice are regularly arranged in a lattice structure.
- Material properties, such as Young's modulus of elasticity, mobility, and piezoresistivity) and chemical etch rates of silicon bulk are orientation dependent.