EE 527 MICROFABRICATION

Lecture 4

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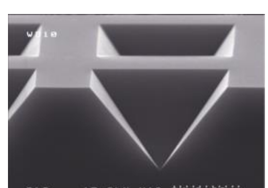
WET ETCHING

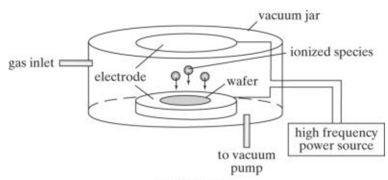
- Most micromachining is presently done with silicon, and a large amount of that is etching with wet chemicals.
- *Isotropic* etchants (e.g. HNA) give rounded profiles.
- *Anisotropic* etchants (e.g. KOH, TMAH) slow down markedly on (111) crystal planes of silicon, yielding flat surfaces.
- Dopants such as high concentrations of boron can be used to stop the progress of etchants such as KOH.
- Electrochemical etch-stop techniques can also be used since at certain potentials, silicon forms an anodic oxide that stops etching.



DRY ETCHING

Overview

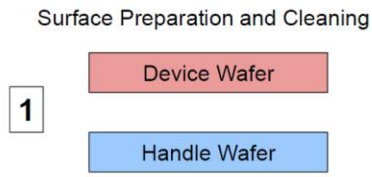
- Vapor Phase Etch:
  - Use of reactive gases
  - No drying necessary
- Plasma Etch:
  - RF energy generates reactive ions and free radicals
  - no high temperatures required (250°C down to room temperature)
- Reactive Ion Enhanced (RIE) Etch:
  - Higher energy ions
  - Higher anisotropy



BONDING BASICS

- Two major classes:
  - Direct bonding (fusion bonding or thermal bonding)
  - Bonding with intermediate layers
- At least theoretically, a wafer of any material can be bonded at room temperature to another wafer of any material via van der Waals intermolecular forces.
- Heating, wetting, and external forces are common techniques to achieve better contact.

OVERVIEW OF WAFER BONDING PROCESS



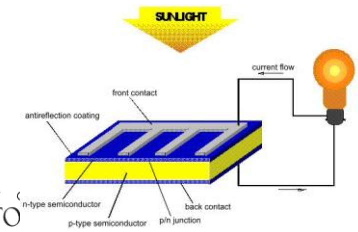
R. B. Darling / EE-502 / Autumn 2011

DIMENSIONS

- Microfabricated systems have minimum dimensions from 20 nm to 50 µm.
- Rule of thumb: alignment is one-third of minimum linewidth
- Rule of thumb: vertical and lateral dimensions of microdevices are similar.
  – If the aspect ratio is more than 2:1, special processing is needed.
- Oxide thickness below 5 nm are used in CMOS as gate oxides and as flash-memory tunnel oxides.
  – Just tens of layers

DEVICES

- Classified by concentrating on fabrication technologies,
  - Volume (bulk) devices
  - Surface devices
  - Thin-film devices
  - Stacked devices
- Examples:
  - Volume devices: power transistor, thyristors, radiation detectors and solar cell



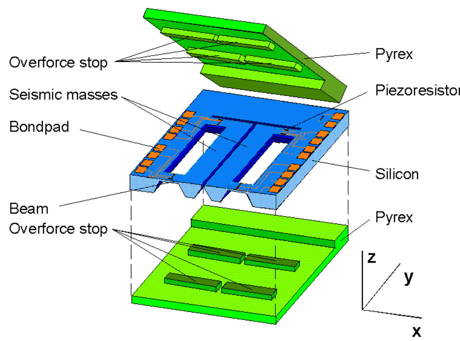
http://solarhaven.co.uk/images/solar-cell-structure.png

DEVICES

- Examples:
  - Surface devices: most of ICs, such as MOS and bipolar transistors, photodiodes, CCD image sensors, as well as optoelectric devices.
  - Thin-film devices: RF switches and relay, optical modulators or DNA arrays.

DEVICES

- Examples:
  - Stacked devices: pressure sensors and accelerometers.



http://www-mat.ee.tu-berlin.de/publications/public96/pics/thv1.gif

CLEANLINESS AND YIELDS

- Dynamic cleanliness: rinse wafers with DI (de-ionized water) during processing.
- Passive cleanliness: cleanroom
  - Careful selection of materials for cleanroom walls, floors and ceilings.
- Yield: the proportion of devices on the wafer found to perform properly.

$$Y = {Y_0}^n$$

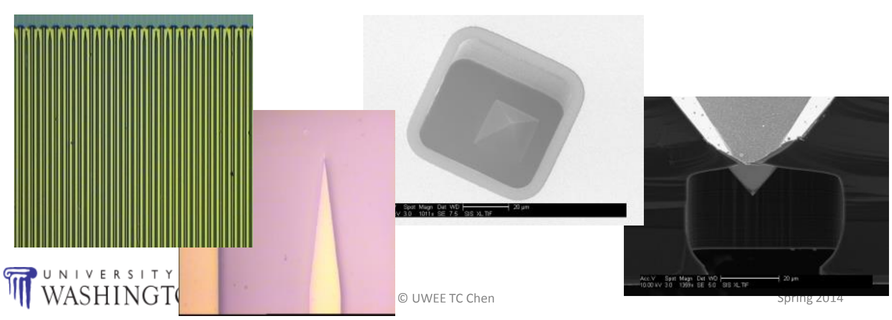
where Y_0 is the yield of a single process step and n is the number of steps.

- As the number of process steps increases, yield Y goes down.
  - 99% single yield with 100 process steps, $Y = 37\%$
  - 99% single yield with 500 process steps, $Y < 1\%$.

MICROMETROLOGY AND MATERIALS CHARACTERIZATION

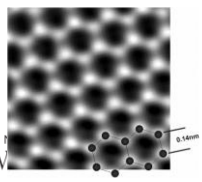
MICROSCOPY AND VISUALIZATION

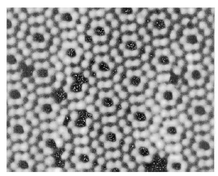
- Optical microscopy:
  - Resolution: micrometer
  - Use: MEMS, solar cell and display devices.
- Electron microscope, scanning electron microscope
  - Resolution: 5 nm
  - Use: tilted and cross-sectional views.

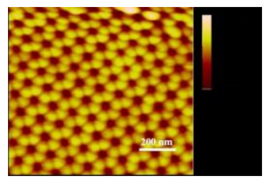


MICROSCOPY AND VISUALIZATION

- Electron microscope, transmission electron microscope
  - Resolution: atomic imaging
  - Use: lattice spacing.
- Scanning probe microscope (SPM) or (STM)
  - Resolution: atomic range
  - Use: surface characterization
- Atomic force microscope (AFM)
  - Resolution: nanometer
  - Use: surface characterization and measuring vertical dimensions.







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