EE 701: Introduction to MEMS

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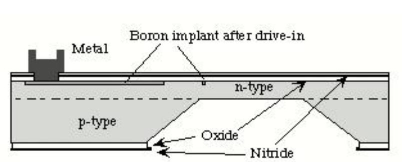
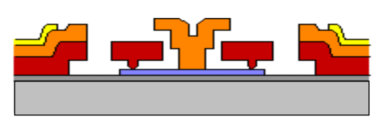
1

Micromachining Processes

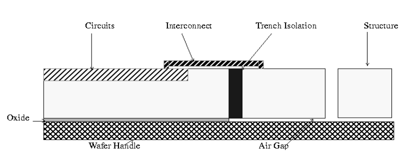
MEMS processing evolved from IC fabrication.



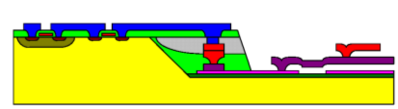
Bulk Micromachining



Surface Micromachining



SOI MEMS Process



Integrated Electronics

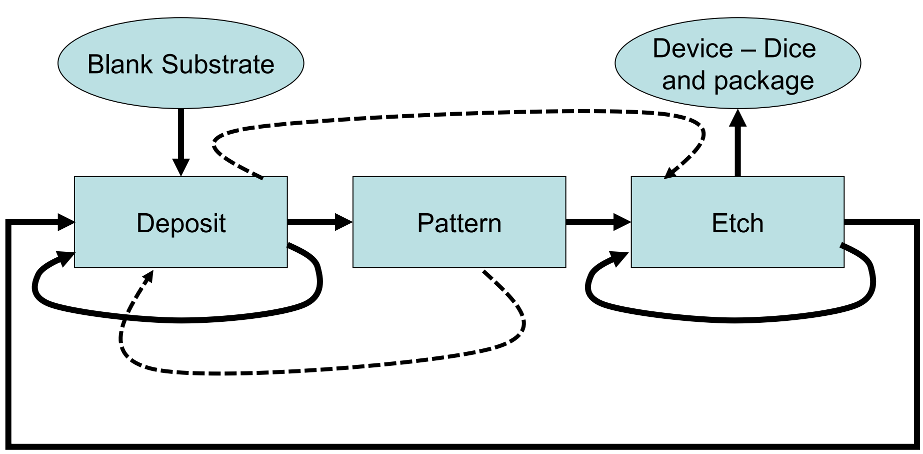
2

Microfabrication

- **Lithography** – definition of structures
- **Deposition** – chemical vapour deposition, evaporation, sputtering, electroplating
- **Etching** – wet (acids, alkali), dry (XeF_2, deep reactive ion etching)
- **Planarization** – chemical mechanical polishing
- **Wafer bonding** – two different wafers or substrates are bonded together.

3

MEMS fabrication sequence



4

Examples of substrates

- Wafers of silicon, quartz, glass, etc.
- Diameters varying from 2” to 12” typically.

- Silicon wafers are manufactured several ways – a common approach is to use the so-called “Czochralski method” or CZ method.
  - Silicon ingots manufactured using this method are then sliced into thin substrates, machined, chemically etched, and polished.
  - Some impurities and defects are incorporated during the process; dopants can also be incorporated by design.
  - Wafer specifications list wafer orientation, thickness variations, wafer bow, doping type and concentration, impurities, etc.
  - Flat edges are ground into the wafer to indicate wafer orientation and dopant type.

5

Pattern transfer/Lithography

- This is the process of defining / writing features or patterns onto a photo-sensitive polymer thin film that is then transferred to an underlying layer or layers.
- The process typically involves spinning on the photosensitive polymer material onto the substrate, curing it, exposing it to the radiation source through a mask, and then development of the resist to remove parts that were (not) exposed to radiation.
- A resist can be either negative or positive tone depending on how it chemically cross-links (or not) on exposure.
- There are also direct write systems for directly writing the features onto the resist using a digital encoding of the pattern but these are typically limited to defining features on smaller areas (~cm scale).

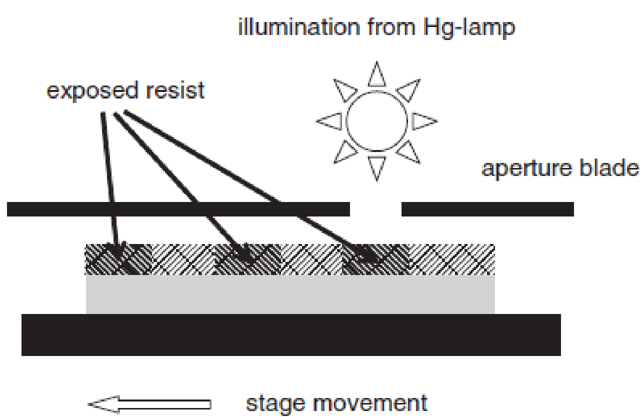
6

Elements of optical/UV lithography

- Radiation source.
- Optics – projection of optical/UV radiation onto wafer through mask.
- Photomask (physical or digital equivalent).
- Chemical resists (positive/negative) – spin coat, pre-bake, exposure.
- Post-exposure bake and resist development.

7

Pattern generation using stage movement



- Consists of a moveable mechanical stage, aperture blade and Hg lamp.

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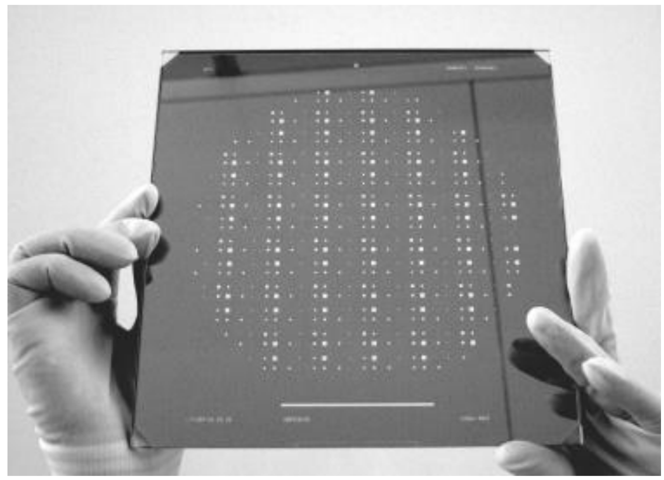
8

What does the mask plate look like?

- Typically glass plates with chromium layers (100nm or so thick).
- A laser beam writer can be used to write the pattern.
- If it is mostly transparent it is known as bright-field mask; otherwise known as dark-field.



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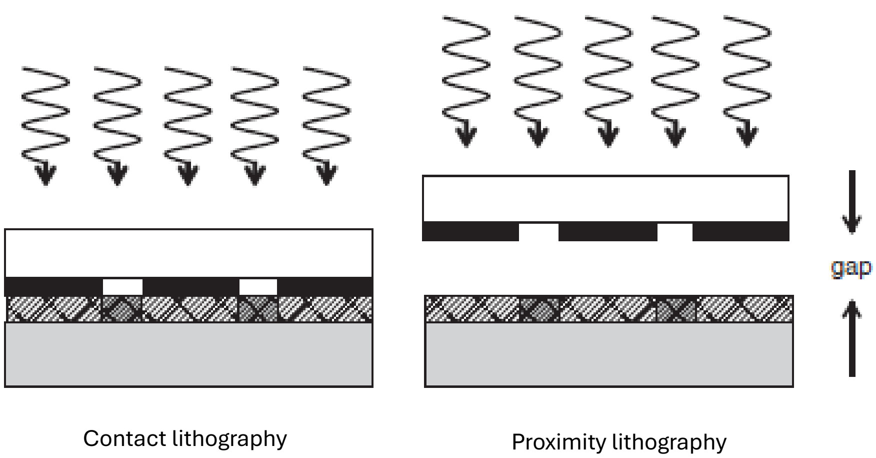
9

Contact versus proximity lithography



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10

The two types of resist (positive and negative)

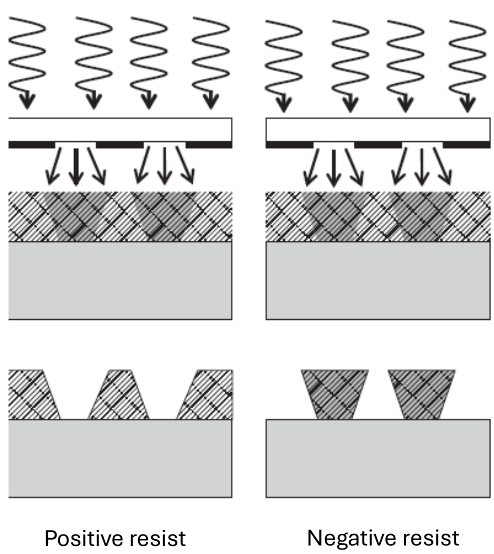
- Positive resist
  - Does not cross-link on exposure to radiation.
  - Exposed areas become soluble in the developer solution.
  - Opaque regions of the mask remain.
  - Usually developed by alkaline solutions such as tetramethyl ammonium hydroxide (TMAH).
- Negative resist
  - Regions that are exposed to radiation are cross-linked.
  - Exposed areas are chemically cross-linked and become insoluble.
  - Opaque regions of the mask are cleared by developer.
  - Usually developed by solvents.

11

Resist profile – positive vs negative resist

Diffraction results in a non-vertical profile. Depending on the type of resist employed, the resulting resist profile can slope differently.

Positive resists are associated with a profile sloping outwards on the edges while negative resists slope inwards.



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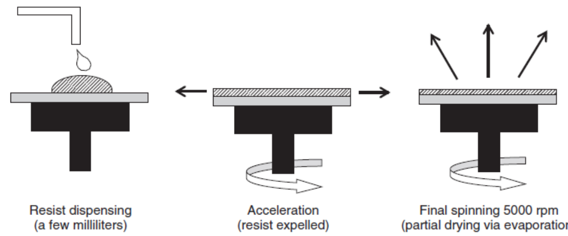
12

Steps in photoresist flow

- Clean wafers, bake, and prime (surface preparation).
- Spin coat resist onto wafer to desired thickness.
- Pre-exposure bake to remove solvent.
- Wafer/mask alignment in mask aligner tool.
- Exposure to radiation (optical/UV) through photomask.
- Post-exposure bake.
- Development of resist (using suitable developer solutions)
- Post-development bake (if needed).



Spin coat of resist

Aligning mask and substrate

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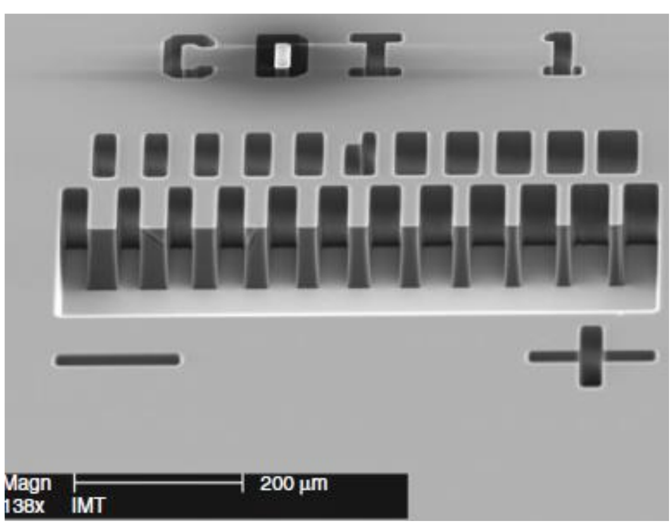
13

Example of positive photoresist after development



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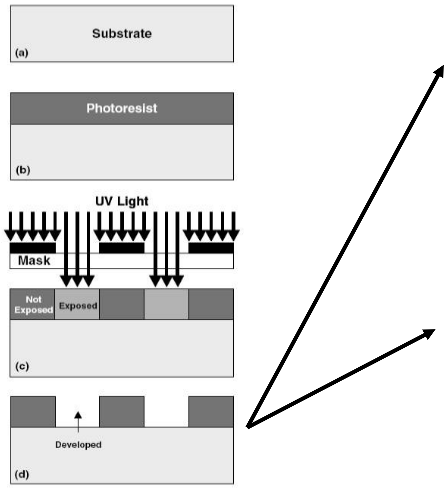
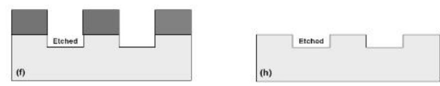
14

Pattern transfer – substrate etch and lift-off processes

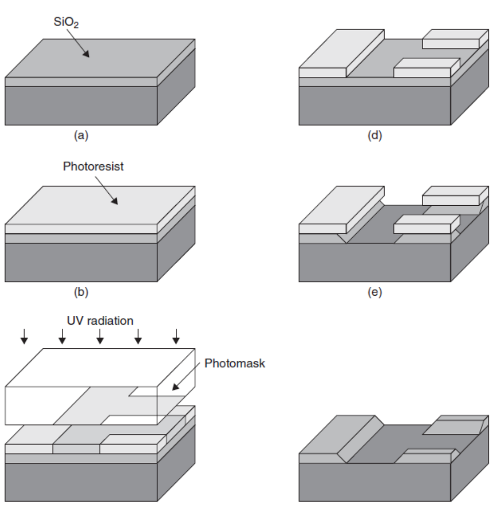


Lift off process
x Thick films difficult to lift off
x Edge profile of resist important
x Remaining deposit edge profile rough



Etch process
- Easier to etch thick films
- Isotropic vs anisotropic
- Resist must 'resist' etchant

Masking for patterning an oxide layer



(a) – Oxide deposition
(b) – Photoresist spin coat
(c) – Photoresist exposed to UV radiation source through photomask.
(d) – Resist developed.
(e) – Oxide film etched.
(f) – Resist removal.

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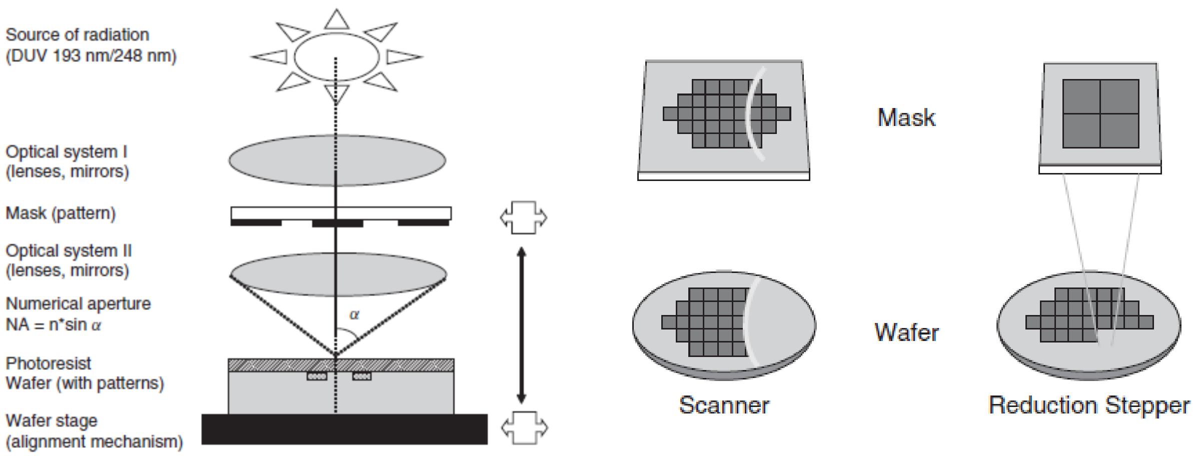
Projection optical lithography systems



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17