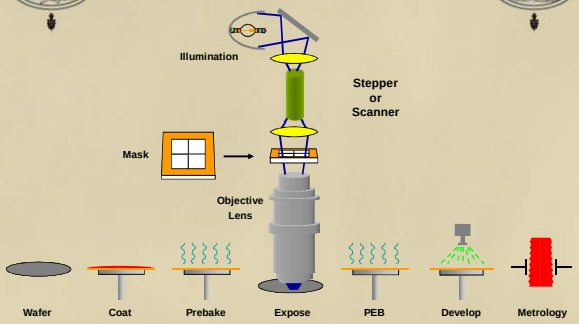
CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323

Lecture 39 Lithography: Process Overview

Chris A. Mack
Adjunct Associate Professor

Reading:
Chapter 7, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

Lithography Sequence



Track and Stepper/Scanner combined into a "photocell"

Lithography Process Requirements

- Faithful reproduction of the mask pattern (obtain the desired critical dimension, CD)
- Allow for pattern transfer (good etch resistance, implant stopping power)
- Good adhesion of photoresist to substrate
- Proper alignment to previous levels
- Ability to strip away photoresist
- Cost effective, safe, and environmentally responsible

The Photoresist

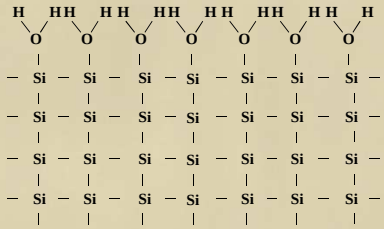
- Photoresist (our photographic film) must be able to both "photo" and "resist"
  - Photo: form a high resolution image, getting the dimensions of all the features right, and with no defects
  - Resist: resist etching in order to transfer the pattern into an underlying layer on the wafer
- Very sophisticated and specialized chemical formulations are required (read expensive!)

Substrate Preparation

- The purpose of substrate preparation is to improve the adhesion of the photoresist material to the substrate
- Sources of Contamination:
  - Particles - eliminate source, chemical or mechanical cleaning
  - Organic Films - chemical, ozone, or plasma stripping
  - Water - dehydration bake, adhesion promoter

Adhesion Promotion

- Water adheres to the dangling silicon bonds at the top surface of the wafer



Adhesion Promotion

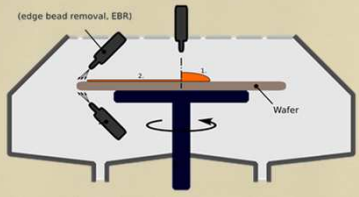
- Dehydrate the wafer surface
  - 100℃ bake
  - Vacuum
  - Nitrogen purge
- Apply Adhesion Promoter to react with dangling silicon bonds
  - Hexamethyldisilizane (HMDS) is applied as a vapor
- Usually performed in the track

Photoresist Spin Coating

A thin film of photoresist is coated onto the wafer by dispensing liquid photoresist and spinning the wafer.

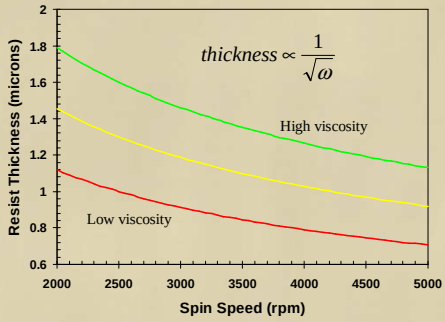
Goals:

- Correct thickness, good uniformity
- Free of particles and pinholes
- Consistent lithographic response



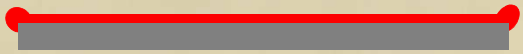
(Image from Wikimedia Commons)

Spin Speed Curve



Photoresist Edge Bead

- Surface tension of the resist causes the formation of an edge bead during spin coating



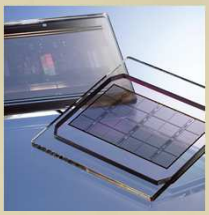
- The edge bead can be several times thicker than the nominal resist thickness

Post-Apply Bake

- The purpose of the post-apply bake step is to remove residual solvent left after the spin coat, resulting in a stable resist film
- Typically 5-15% solvent remains after the post-apply bake
- Also called softbake or prebake

The Photomask

- A photomask (also called a reticle, or just mask) contains what you want to print on the wafer as opaque patterns on a transparent substrate

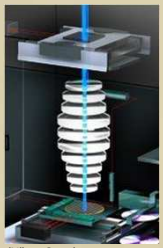


- 6" square fused silica (quartz) substrate, ¼" thick
- Opaque regions are made of chrome or molybdenum silicide (MoSi)
- Making the photomask uses its own lithography process, usually by using beams of electrons to expose a resist
- Patterns on the photomask are defined by the chip design data
- Typical mask is 4X bigger than the wafer patterns

(Toppan Photomasks)

Exposing the Photoresist

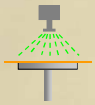
- The heart of the lithography process is imaging the photomask onto the wafer
  - Before exposure, the mask and wafer must be aligned so that the new pattern lines up with existing patterns on the wafer
  - Light from a laser shines on the mask
  - Transmitted light is collected by a very sophisticated (and expensive) imaging lens
  - Image of the mask is projected onto the photoresist coated wafer
  - Only a portion of the wafer is exposed at one time, so the wafer is stepped and/or scanned under the lens to record multiple copies of the mask image



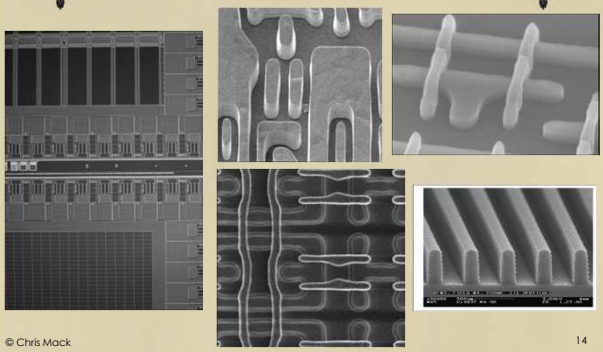
(Nikon Corp.)

Developing the Image

- Once exposed, the wafer comes out of the scanner and back into the track
- First the wafer is baked on a hotplate to complete the chemical changes caused by exposure
- Then the wafer is developed
  - Developer is poured or sprayed onto a slowly spinning wafer
  - Positive resist: developer removes the exposed parts
  - Negative resist: developer removes the unexposed parts
  - A good resist is "high contrast" – a very nonlinear response to exposure



Result: Patterns Printed in Photoresist



Lecture 39: What have we Learned?

- How many requirements for lithography can you name?
- What are the two main tasks of a photoresist?
- How does an adhesion promoter work?
- What is the relationship between resist thickness and spin speed?
- What is an edge bead, why does it occur, and what do we do about it?
- What is the purpose of a post-apply bake?
- Explain the two tones of photoresists