EE 527 MICROFABRICATION

Lecture 17

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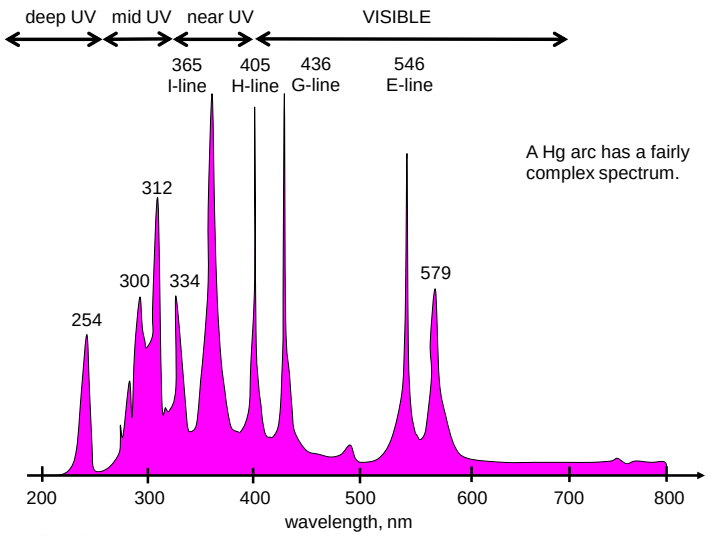
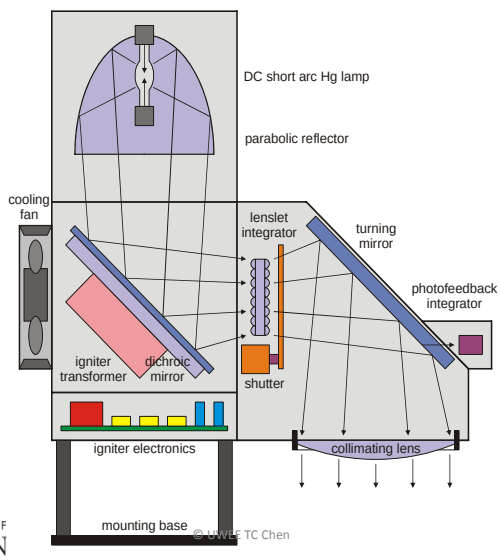
EXPOSURE SOURCES

- Photons
  - white light
  - Hg arc lamp (all lines)
  - filtered Hg arc lamp (g-line 435 nm, h-line 405 nm, i-line 365nm)
  - excimer laser (KrF 248 nm, ArF 193 nm, F_2 157 nm)
  - x-rays from synchrotron
- Electrons
  - focused electron beam (e-beam) direct write
- Ions
  - focused ion beam (i-beam) direct write

HIGH PRESSURE HG ARC LAMP SPECTRUM



DC SHORT ARC LAMP SOURCE AND HOUSING



EXPOSURE OPTIONS: THE HG ARC SPECTRAL LINES

- 578.2 nm: (yellow-orange)
- 546.1 nm: (green)
- 435.8 nm: g-line (blue)
- 404.7 nm: h-line (violet)
- 365.4 nm: i-line (UVA)
- 334-335 nm: (UVA)
- 312-313 nm: (UVB)
- 297-302 nm: (UVB)
- 253.7 nm: (UVC)
- 184.45 nm: (UVC)

Too long in wavelength for lithography.

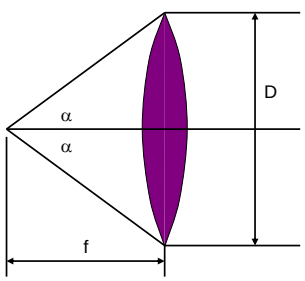
Sharp emission lines which are best suited for photolithography exposure and matched well to the absorption characteristics of most photoresists.

Emission lines are blurred together and difficult to separate. Imaging optics would have to employ significant color correction. Not that much intensity, either.

Have insufficient intensity for use in photolithography.

LENS APERTURES

- The f-number of a lens ($f/\#$) is the focal length divided by the diameter. It is a measure of the light gathering ability.
- The numerical aperture (NA) of a lens is $n \times \sin\alpha$, where α is the half-angle of the largest cone of light entering the lens.



$$\frac{f}{\#} = \frac{f}{D}$$

$$\mathrm{NA} = n \sin\alpha$$

$$NA = \frac{1}{2}\frac{D}{\sqrt{\frac{D^2}{4} + f^2}} \approx \frac{D}{2f} = \frac{1}{2 \times f/\#}$$

PROJECTION LITHOGRAPHY REQUIREMENTS

- b = minimum feature size (spot or line)
- 2b = minimum period of line-space pattern
- λ = exposure wavelength
- Using $b = f\,\theta_{min}$, obtain that $b \approx \lambda f/D = \lambda/2NA$.

Sample Calculation

- A primary reduction camera uses a projection lens with f/6.8 and f = 9.5 in. = 241.3 mm.
- The lens diameter is D = 241.3 mm/6.8 = 35.5 mm = 1.40 in.
- The numerical aperture is NA = 1/2*6.8 = 0.074.
- For exposure in the middle green, λ = 550 nm.
- Thus, the minimum feature size is b = 550 nm/2*0.074 = 3.72 μm

CONTACT AND PROXIMITY LITHOGRAPHY RESOLUTION

- λ = exposure wavelength
- d = resist thickness
- 2b = minimum pitch of line-space pattern
- s = spacing between the mask and the resist
  - Contact Printing:

$$2b = 3\sqrt{0.5\lambda d}$$

    - At λ = 400 nm, d = 1 μm, obtain b = 0.7 μm linewidth.
  - Proximity Printing:

$$2b = 3\sqrt{\lambda d(s + 0.5)}$$

    - At λ = 400 nm, s = 10 μm, d = 1 μm, obtain b = 3.0 μm linewidth.