Exercise

a) Photolithography

An excimer laser produces radiation at 157 nm, and optics with a numerical aperture of 0.8 is available.
What is the smallest size of feature you could make in a resist?

b) Photolithography

A way to increase the resolution in photolithography is to increase the numerical aperture *NA*.
How could one achieve that without changing the lens diameter?

c) e-beam lithography

Calculate the wavelength of electrons with $E = 100$ keV.

d) e-beam lithography

The point spread function (PSF) represents the spatial distribution of the energy deposited in the resist from a single point of incidence.

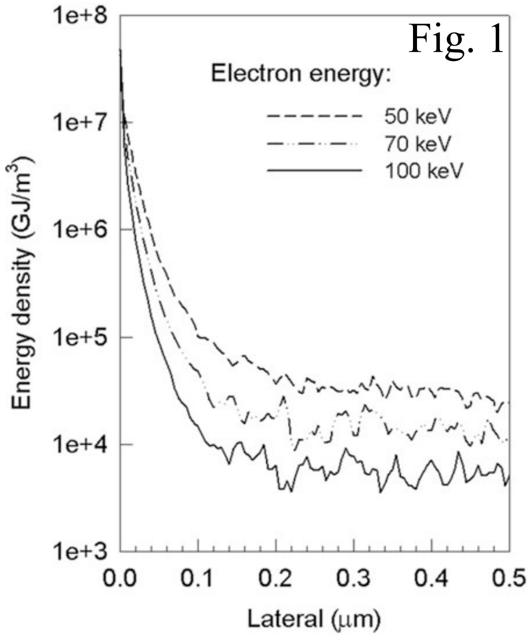
Figure 1 shows a comparison of PSF at different electron energies (0.5 µm resist thickness, Si substrate).

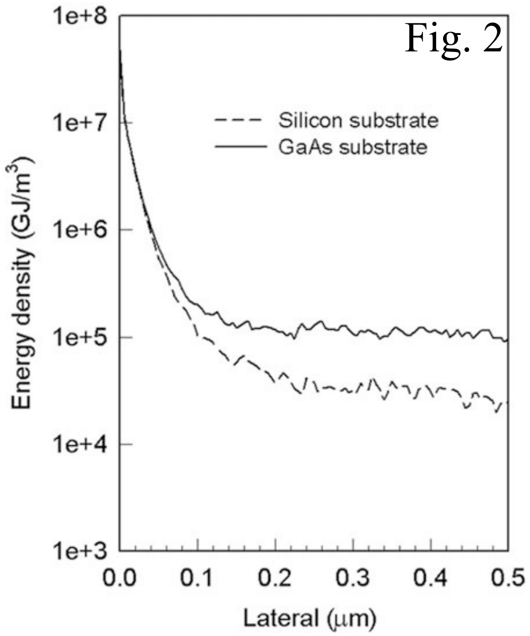
Figure 2 shows a comparison of PSF for different substrate materials (50 keV beam energy, 0.5 µm resist thickness).

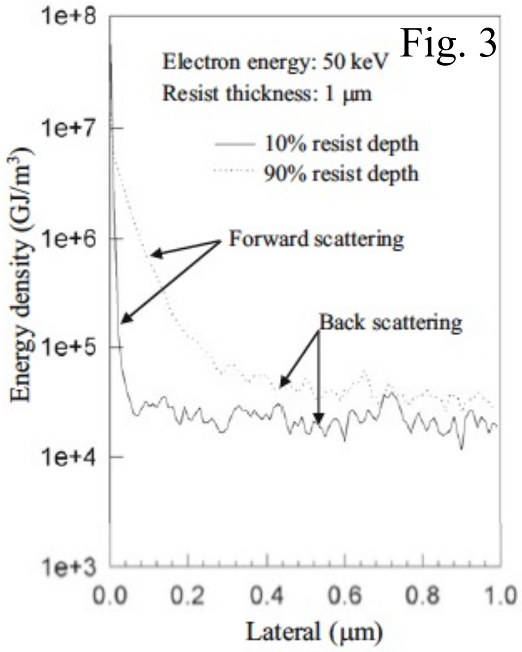
Figure 3 shows a comparison of PSF at different depths in the resist (50 keV beam energy, 1 µm resist thickness).

We want to achieve the highest resolution. Is it better to use:

- higher or lower electron energy?
- a denser or a lighter substrate as support for the resist?
- a thicker or a thinner resist film?







Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer 2024

Solution - Exercise

a)

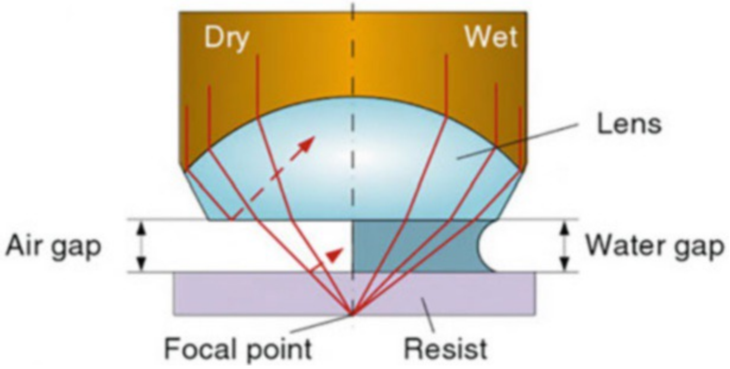
$$R = k_1 \frac{\lambda}{NA} \qquad \text{with } \lambda = 157 \text{ nm and } NA = 0.8, \quad \text{assuming } k_1 = 0.5 \qquad \rightarrow \qquad R \approx 100 \text{ nm}$$

b) $NA = n \sin\theta$

It is possible to increase NA by using **immersion (wet) optical lithography**: changing the medium between the resist and the lens, and choosing a medium with higher refractive index n (typically a liquid)

air: $n = 1$

water: $n = 1.437$



c) e-beam lithography

$$\lambda = \frac{1.226}{\sqrt{eV}} \text{ nm} \qquad \text{with} \quad E = 100 \text{ keV} \quad \rightarrow \quad \lambda \approx 3.9 \text{ pm}$$

d)

- Figure 1 shows that the energy deposited away from the point of incidence is lower for electrons with higher energy → it is better to use high electron energy (the resist is modified “only” in the desired region).
- Figure 2 shows that for Si (lighter) the energy deposited away from the point of incidence is lower than for GaAs (heavier) → it is better to use light substrates.
- Figure 3 shows that going deeper in the resist the deposited energy spreads more in space → it is better to use thin resist layers