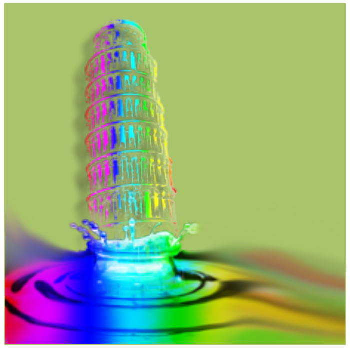
CENTRO E. PIAGGIO
Bioengineering and Robotics Research Center

IN SUPREMÆ DIGNITATIS
1343



# Lithography

G. Vozzi

# Lithography

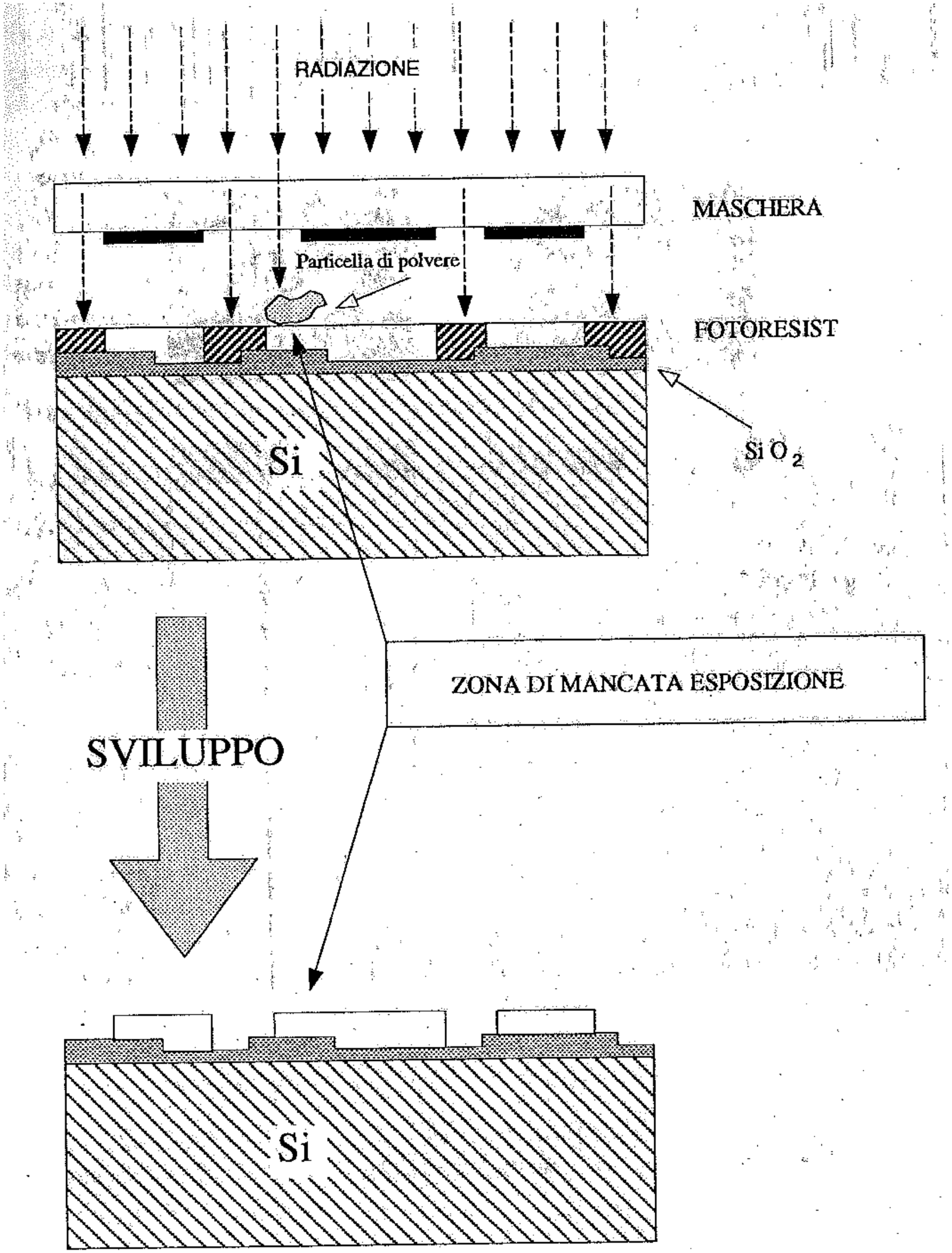
**1796**

**Aloys Johann Nepomuk Franz Senefelder**

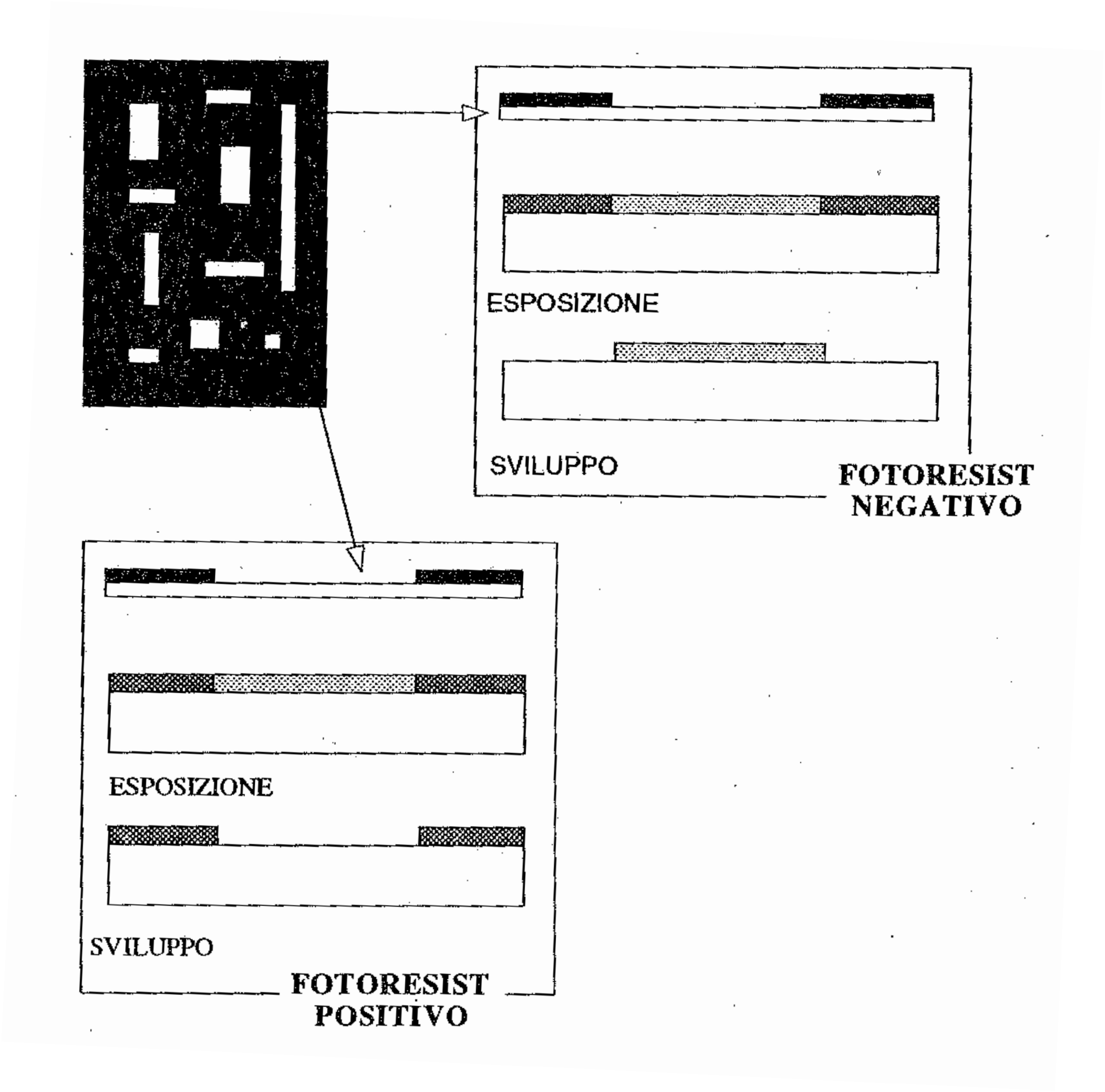
He is experimenting with different techniques Niépce managed to obtain, in 1826, his first image drawn by the light (after applying a layer of bitumen of Judea reduced to powder and dissolved in lavender essence; the solution is brushstroke on a copper foil coated with silver, and then allowed to dry; the photoresist coating layer is exposed for a few hours on the bottom of a darkroom; subsequently the foil is immersed in a bath of lavender to dissolve the fragments that have not received the light, and so you get the picture in the negative. For the positive we should be a container with iodine crystals that form of silver iodide deposits; removing the paint with alcohol appears the photographic image itself) that defines eliografia, the mother of modern photography.
The unique and unexpected that the result of his work is not fixed, and then gradually darkens on contact with the light. His commitment is devoted, in recent years, the improvement of image sharpness. In 1827, during a trip to Paris, he met Daguerre and Lemaitre who later become his collaborators..

# Steps of lithographic process

- Photoresist deposition
- Soft baking
- Exposure
- Hard baking
- Development
- Rinsing


RADIAZIONE
MASCHERA
Particella di polvere
FOTORESIST
Si O$_2$
Si
ZONA DI MANCATA ESPOSIZIONE
SVILUPPO
Si

# Negative and Positive Photoresist



# Spinning process

$$sp = \frac{KS^2}{\sqrt{V}}$$

Sp= thickness of photoresist
S=volumetric fractio of photoresit
V= rotation speed
K= function led to viscosity and spinning device

# Alternative methods of deposition

**Spray deposition**

Its success depends on a good by:

- Dilution of the photoresist
- spray speed
- Geometry and output characteristics of nozzle
- atomizing pressure
- wafer-spray distance
- power mode of the nebulizer

**Coil coating**

# Soft-baking

The soft baking allows to eliminate most of solvent present in the photoresist and influences the exposure and the development.

A reduced softbaking (in time or temperature) involves an excess of solvent which damages the exposure and favors the removal of unexposed areas.

Prolonged softbaking (on time or temperature) degrade the sensitivity of the photoresist

# Soft-baking Methods

Usualt temperature 80-90°C.

- **Infrared** (700 nm - 1mm). It allows to heat the resist from the inside and not there is the formation of bubbles
- **Thermal conduction.** Hotplate or controlled oven
- **Microwave** (0.1 mm - 1 mm, f = 2.5 GHz).

# Exposure

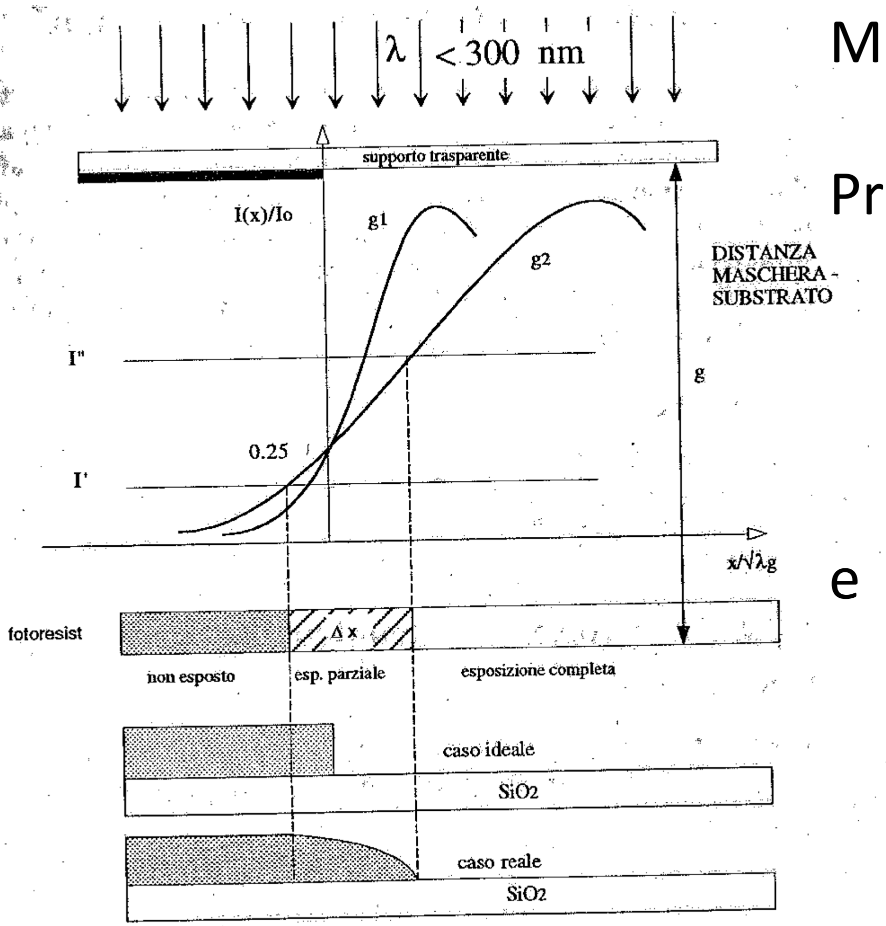
- Contact exposure
- Exposure in proximity
- Projection exposure

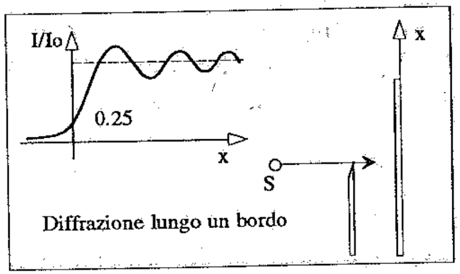
- Contrast defines the resist

$$\gamma = \frac{1}{\log \frac{Q_2}{Q_1}}$$

Where Q=I*t= dose
I= Radiation Intesity
T= Exposure time
Q1= dose that allows the initial exposure
Q2= dose that allows the complete exposure

# Exposure





Diffrazione lungo un bordo

Miminum dimension

Projection exposure

$$d_{\min} = 15\sqrt{\frac{\lambda_g}{200}}$$

e

$$d_{\min} = \frac{0.8\lambda}{NA}$$

# Steps of lithographic process

- Photoresist deposition
- Soft baking
- Exposure
- Hard baking
- Development
- Rinsing

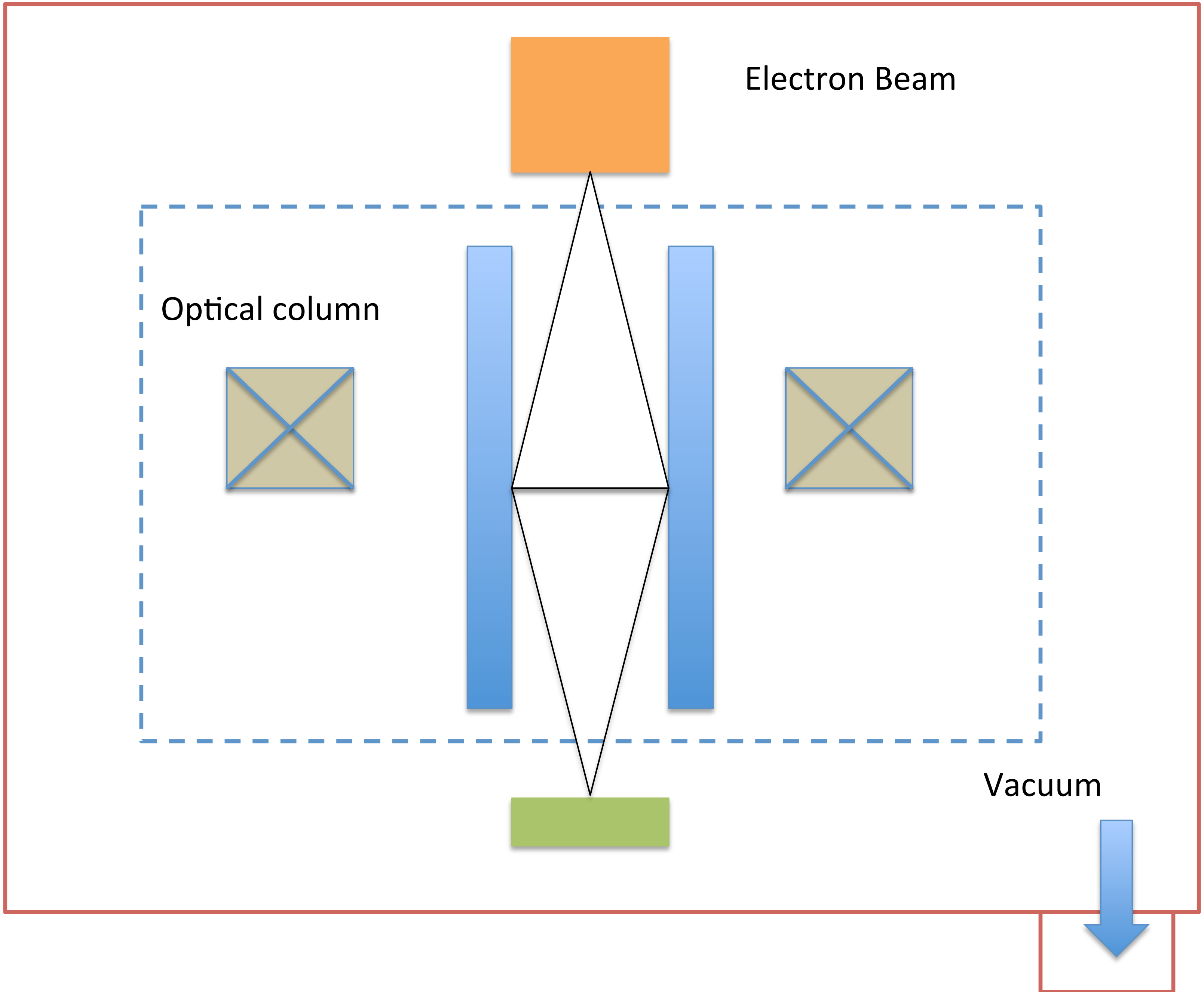
# Numerical aperture

NA = numerical aperture is a dimensionless number that indicates the maximum useful angle to the system (lens, condenser lens or similar) to receive or emit light.

$$NA = nsen\frac{\alpha}{2}$$

where n is the refractive index of the medium in which the lens, and α / 2 is the angular aperture of the lens, that is the half angle of the cone of light that enters the optics. The higher NA, better, at the same focal, is the optics. The theoretical limit of the angle of the light cone, 180 °, is never reached, and in practice the maximum value is about 143 °. To increase the NA value is often intervenes on the medium, using, instead of the air, natural or synthetic oils, of higher refractive index and as close as possible to that of glass (the coverslip and the lens), with the 'further advantage of eliminating the passage of light between different means with relative diffusions and reflections. By contrast, an increase in the opening enhances any optical aberrations and, as in photography, reduces the depth of field. To obviate this latter aspect, for special observation situations and in high-end tools, there are microscopic objectives with variable aperture diaphragm.

# Electron beam



Electron Beam

Optical column

Vacuum

# Electron Beam

Tungsten filament, which ejects electrons due to the thermionic effect

$$J_c = AT^2 e^{-(\frac{\varphi_m}{kT})}$$

$$A = \frac{4\pi m k^2 e}{h^3} = 1,20173 \cdot 10^6 \frac{A}{m^2 K^2}$$

A= Richardson Constant
Φm=metal work function

The filament is working a few KV and a few hundred KV

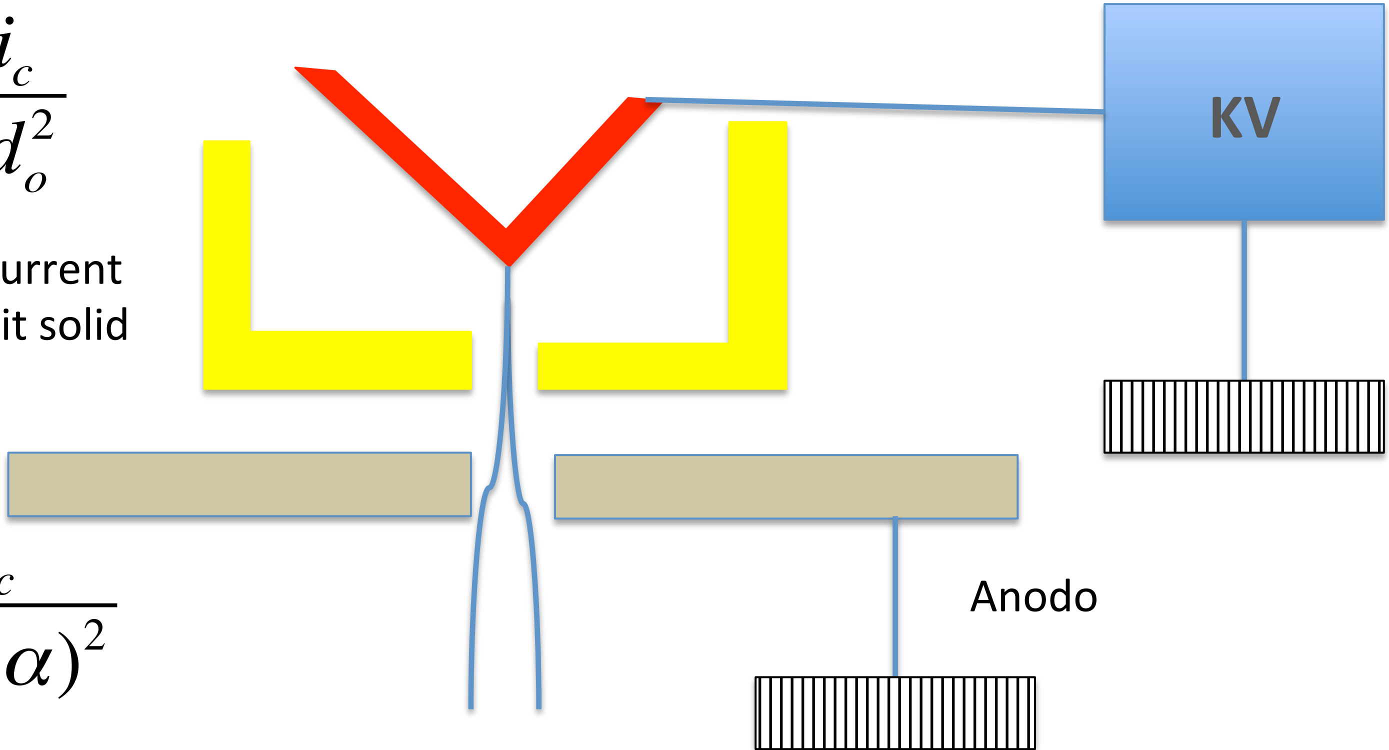
# Electron Beam

- Anode kept grounded
- An electrode in the vicinity of the filament which is held at a negative potential for collimating the electron beam

$$J_{co} = \frac{4i_c}{\pi d_o^2}$$

Luminance = current density per unit solid angle

$$\beta = \frac{4i_c}{(\pi d_o \alpha)^2}$$



# Electron Beam

- Generally it has a 100 ° emission beam A with respect to the diameter of 100 micrometers of the cross-over
- The life of the filament is 200 hours for 2500 ° K 5 hours if the temperature is 2900 ° K
- Generally is used Esaboruro lanthanum (LaB6) filaments which allow to have a function of lower labor, higher emission current density, the lowest working temperature, higher brightness, smaller crossover diameter and greater durability.

# Electro beam lithography

- Wavelength uses 0.2-0.5 A ° which limits the diffraction
- It works directly on the wafer without mask
- You can make subsequent entries with a good positioning of the beam

Problems

- The resolution gets worse because of scattering of primary and secondary electrons in the resist
- Swelling phenomena of photoresist
- slow process
- expensive process (3-5 times the optical one)

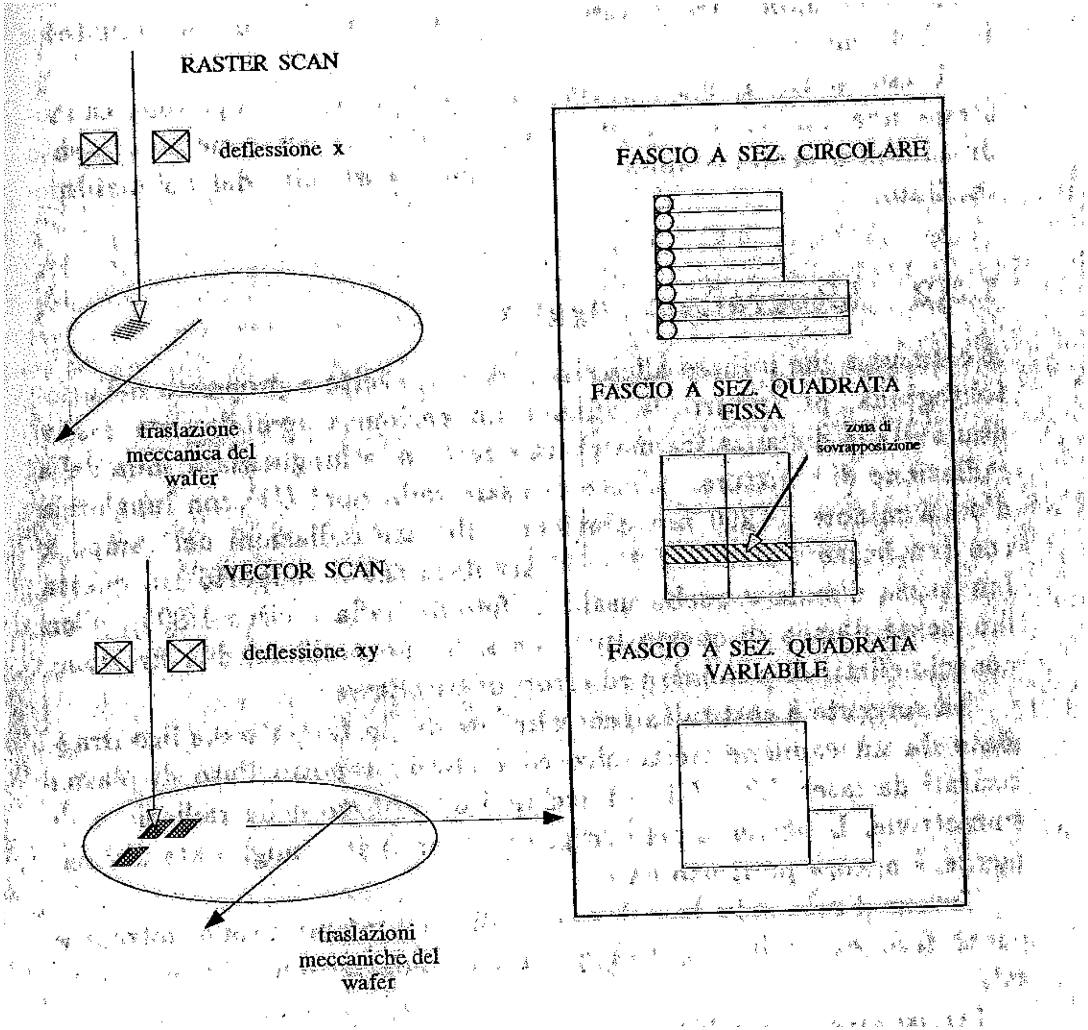
# Electro beam lithography

The electron beam is about 400 °A, while the source has a diameter between 10 and 100 micrometers and then the electron gun must reduce the times of 100-1000 times

The reduction must be minimizing the aberrations of lenses.
Typically this is a shifter with a positioning accurancy equal to 0.01 micrometers and speed of 10 cm / sec which moves the wafer under the electron beam.

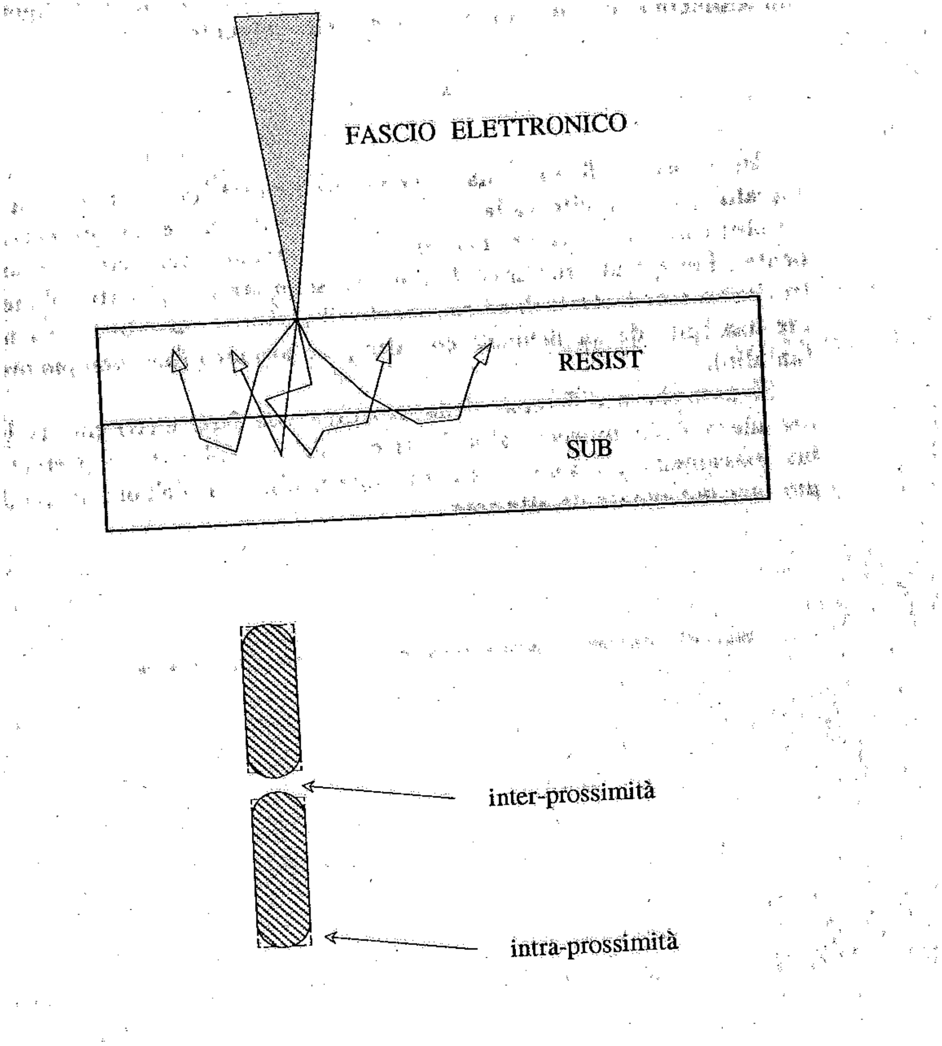
The writing techniques are:
raster scan
Vectort scan

# Electro beam lithography



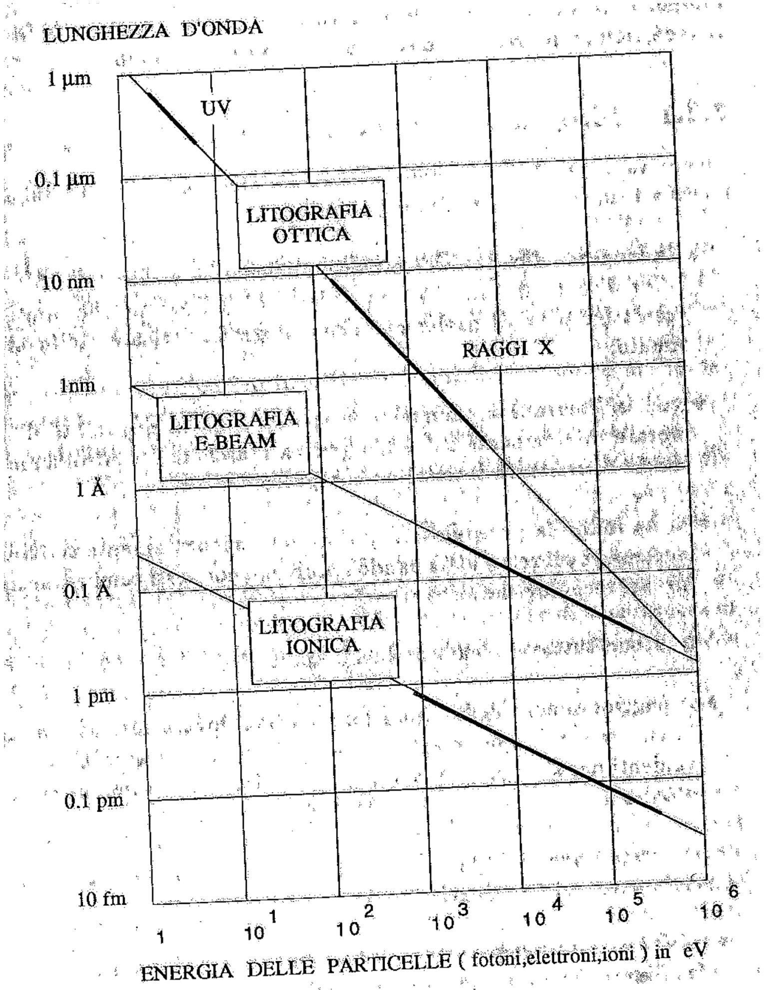
# Electro beam lithography

- Inter proximity effect
- Intra proximity effect



# Advanced Lithographic techniques

- UV radiation limits around the micron
- Electron beam lithography resolution 0.4 micrometers
- X-ray lithography resolution 12:25 micrometers
- ion beamslithography  resolution 0.2 micrometers



# X ray lithography

Wavelength of 10 nm to 1 pm.

The source is usually a metal irradiated by an electron beam.

The sources of x-ray sources are isotropic and do not give collimated beams.

The resists are based on polymethyl methacrylate, which is depolymerized after the absorption of the radiation in rays X.

# X ray lithography

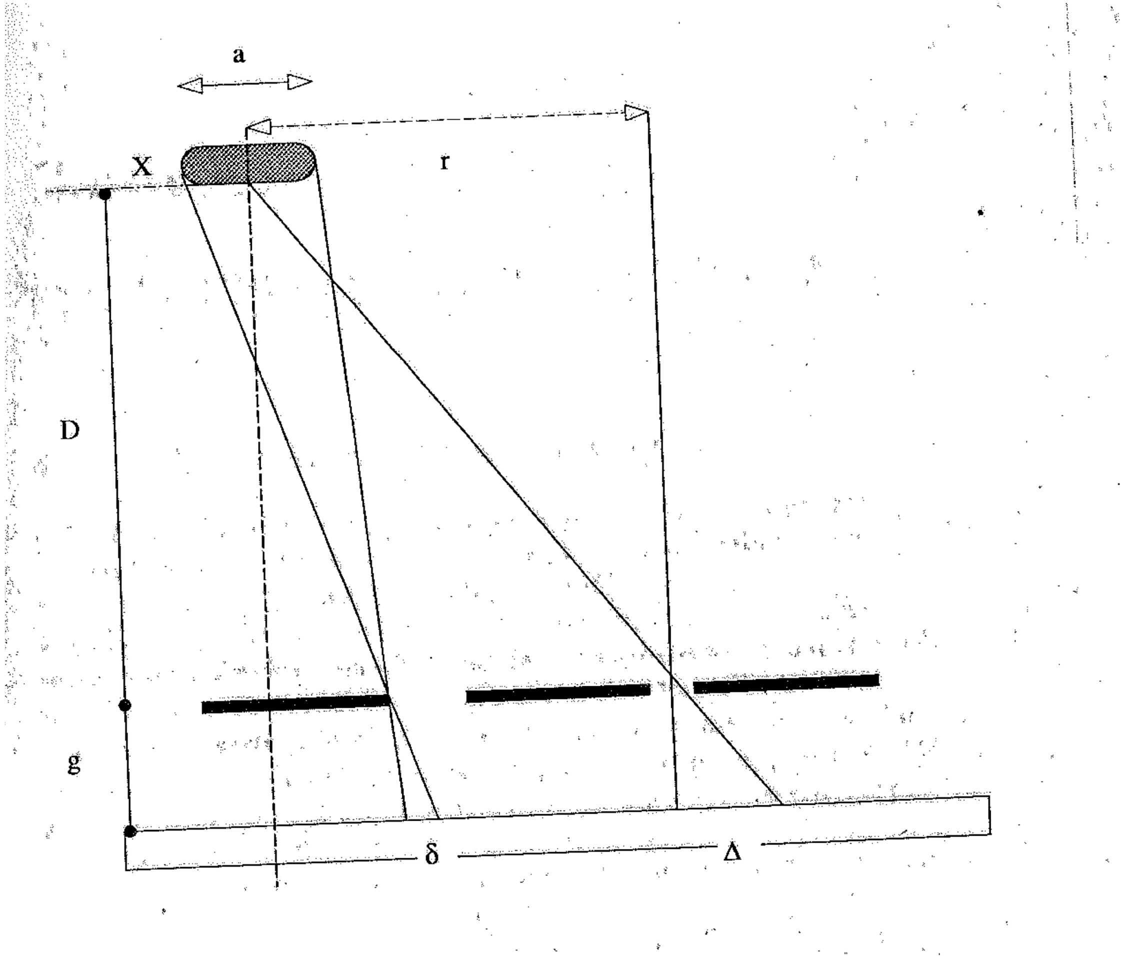
With this type of radiation you will only have the penumbra problems and parallax errors.

- Penumbra error

$$\partial = \left(\frac{g}{D}\right)a$$

- Parallax error

$$\Delta = \left(\frac{g}{D}\right)r$$



The masks are typically made of mylar and / or thin silicon layers and the absorbent material is gold, lead or tantalum