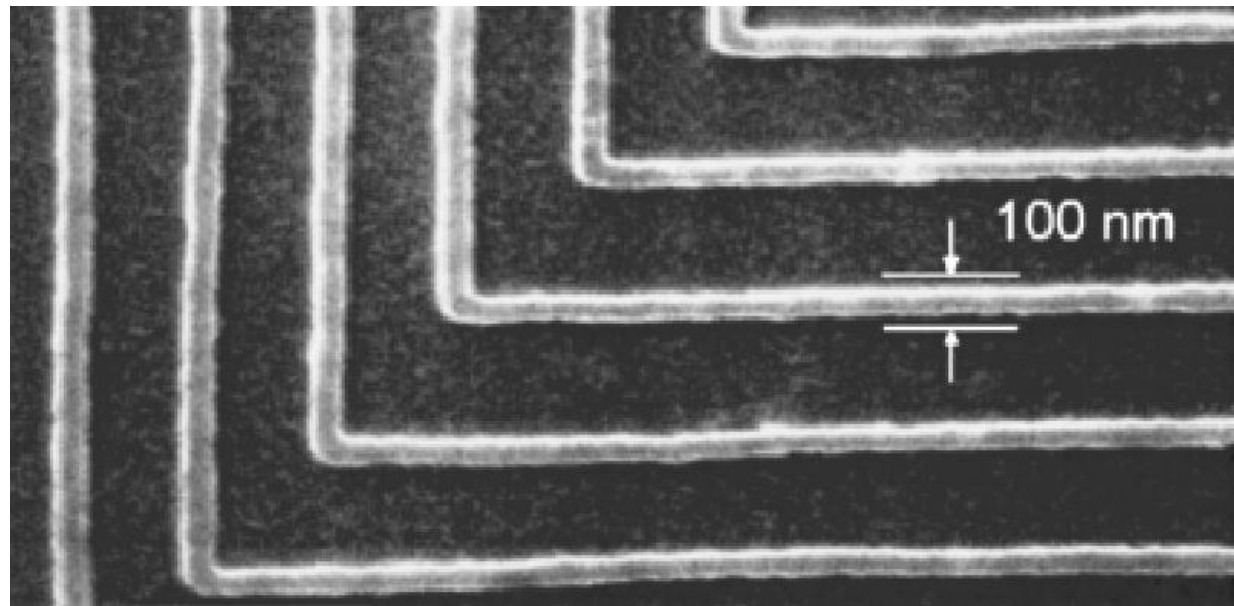
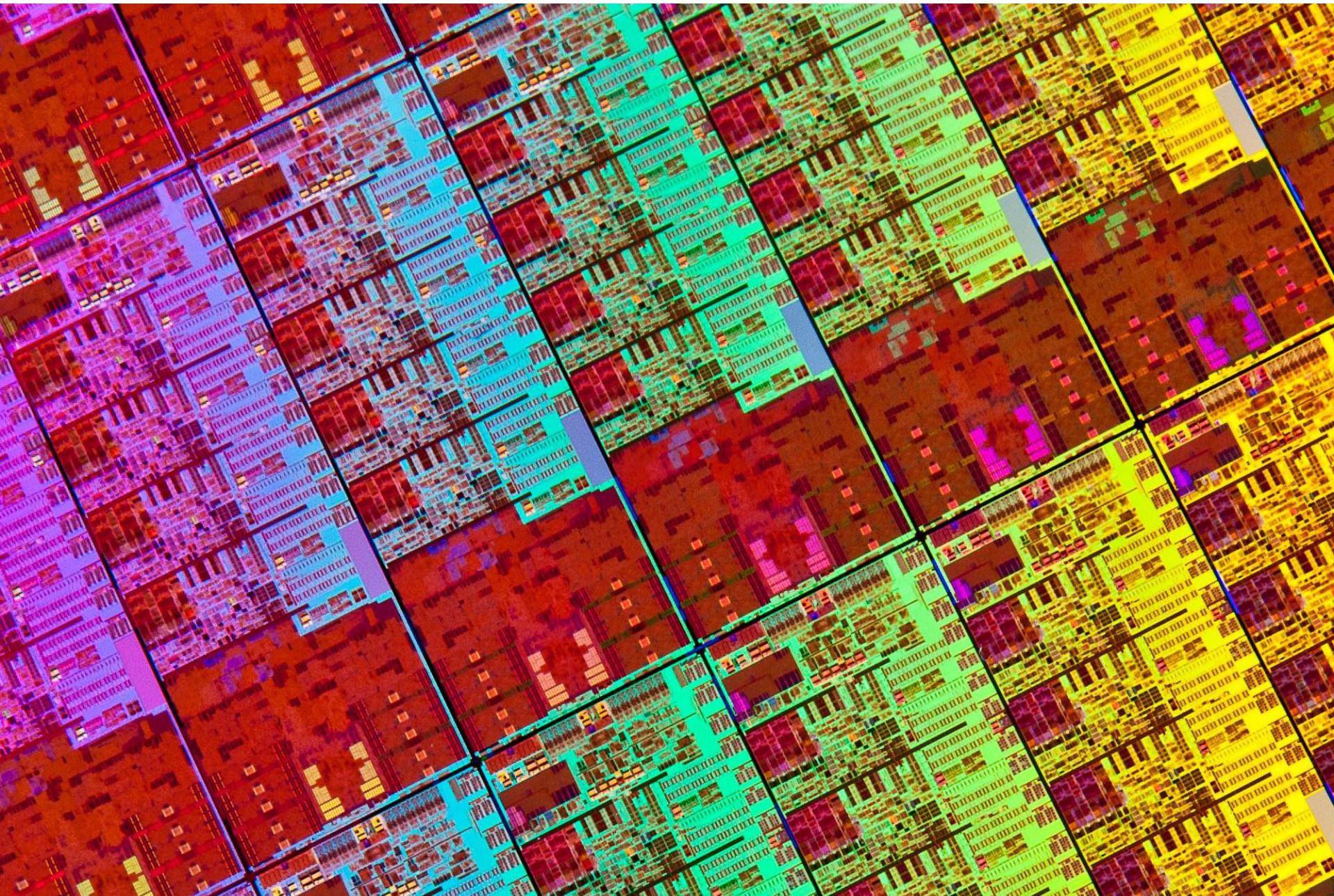
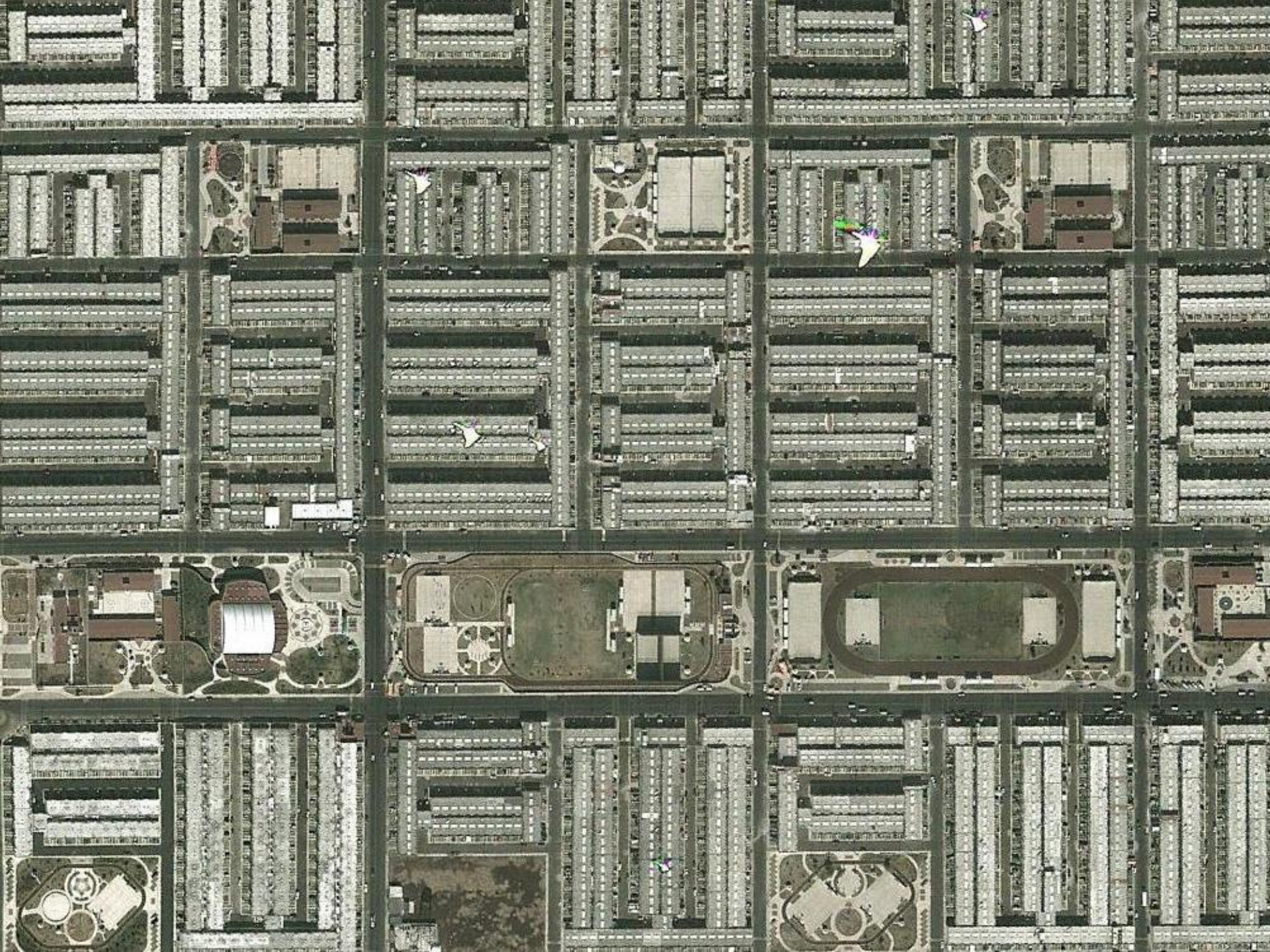
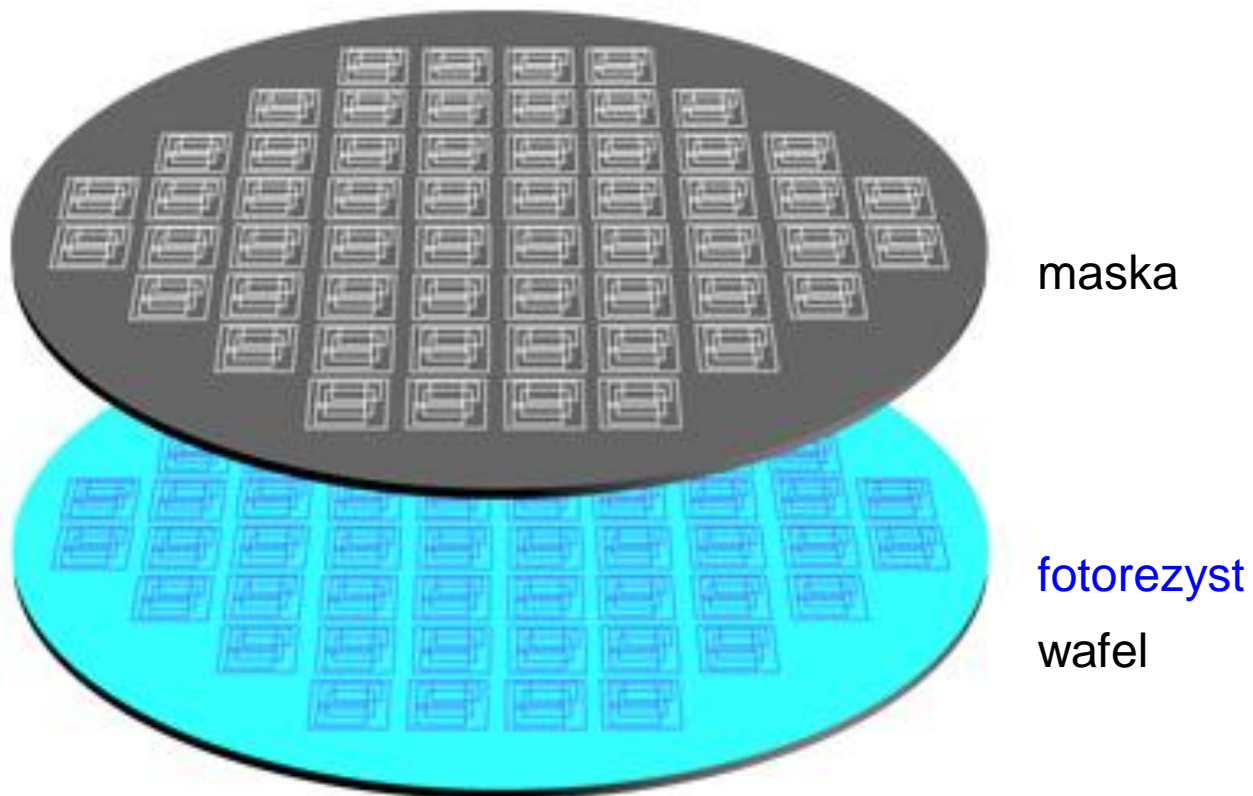


**fotolitografia**









- przenoszenie obrazu z szablonu na powierzchnie
- tworzenie tymczasowego obrazu materiałowego

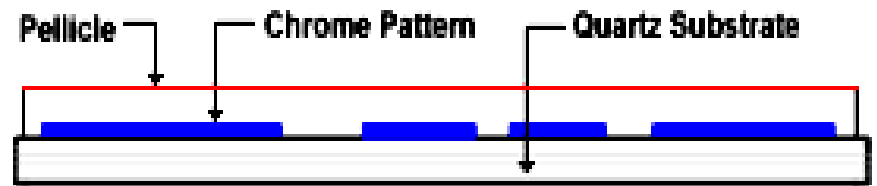
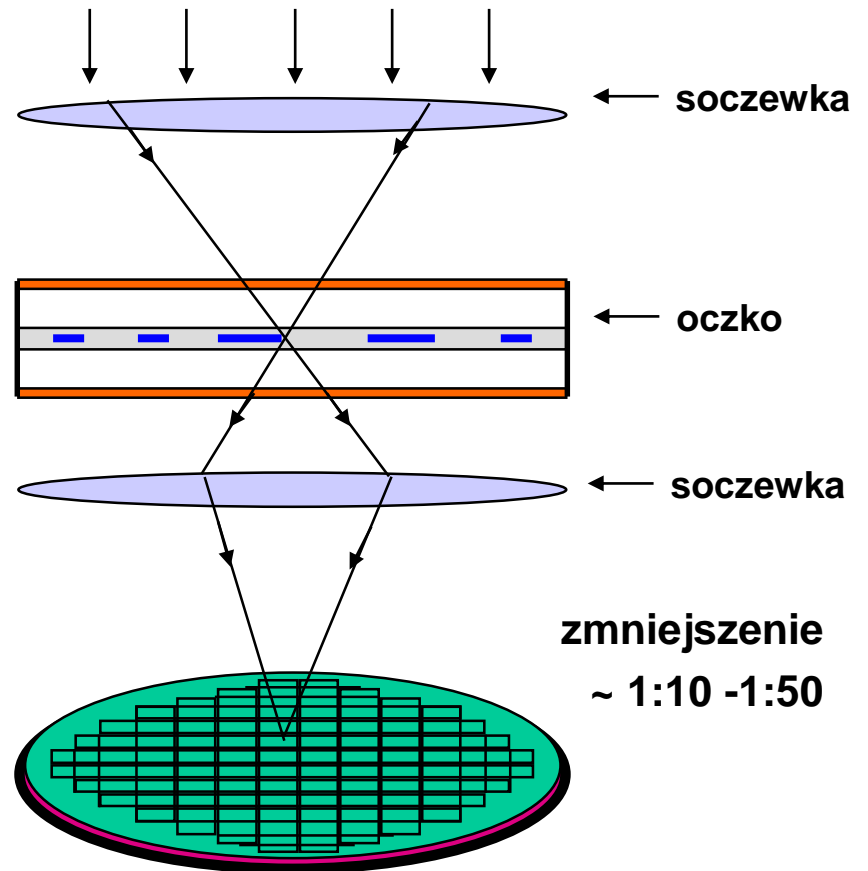
projekcja pojedynczego pola  
→ lepsza powtarzalność



**stepper**  
~ 50 wafli/hr



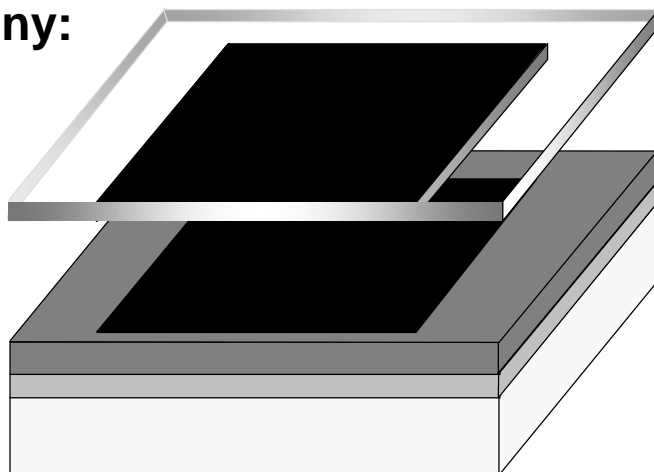
zestaw oczek dla tranzystora



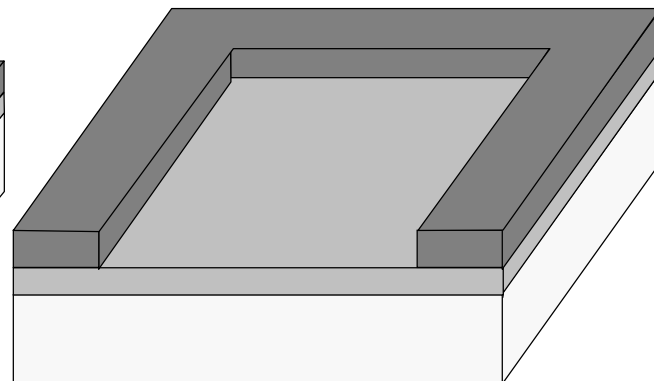
**Reticle**

fotorezyst **negatywny**:

rozpuszczalność  
polimeru maleje

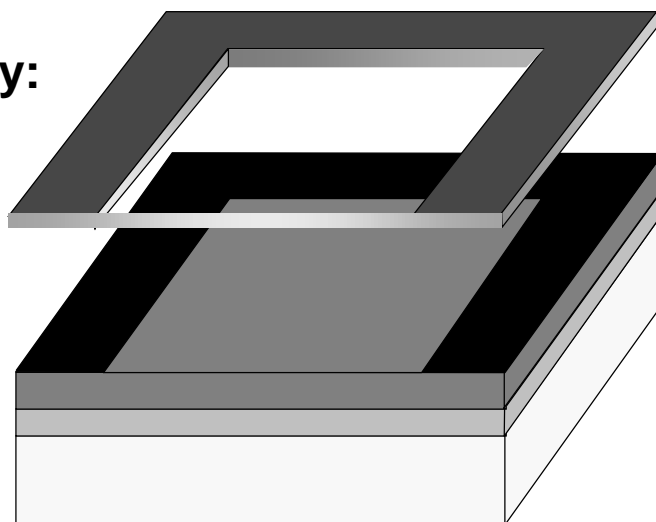


obraz **odwrotny** do maski

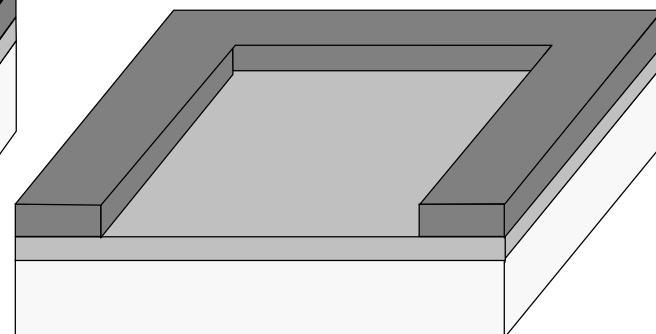


fotorezyst **pozytywny**:

rozpuszczalność  
polimeru wzrasta

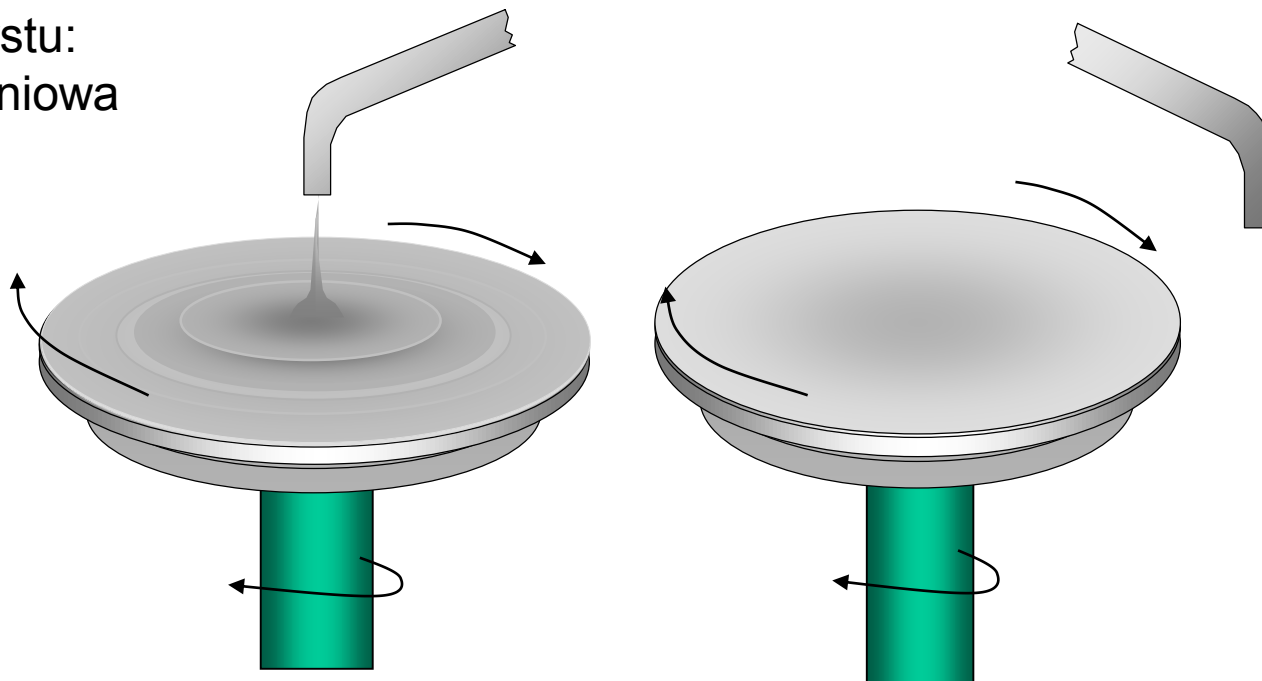


obraz **podobny** do maski



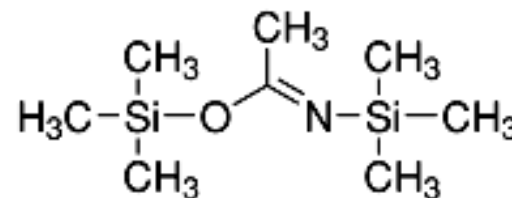
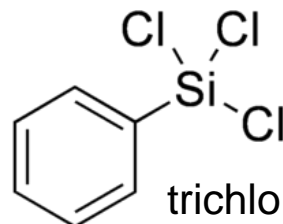
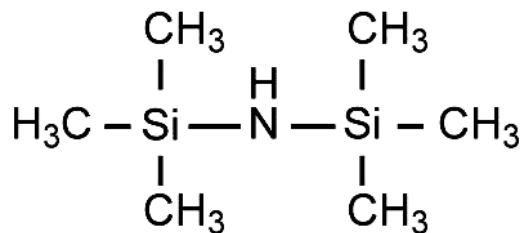
nałożenie fotorezystu:

- podstawa próżniowa
- nalewanie
- 500 rpm
- 4000 rpm



promotorzy adhezji:

**1,1,1,3,3,3-hexamethyldisilazane (HMDS)**

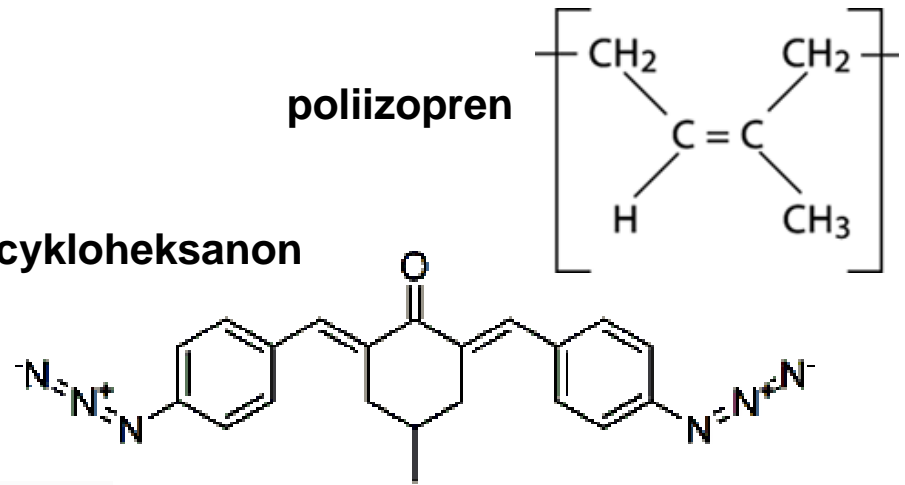


bis(trimethylsilyl)acetamide (BSA)

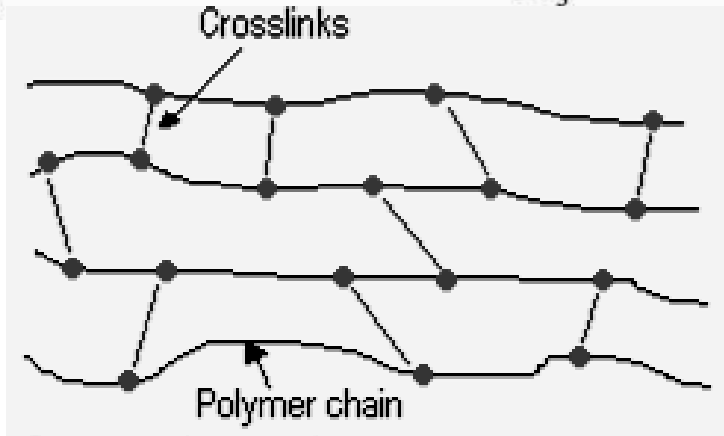
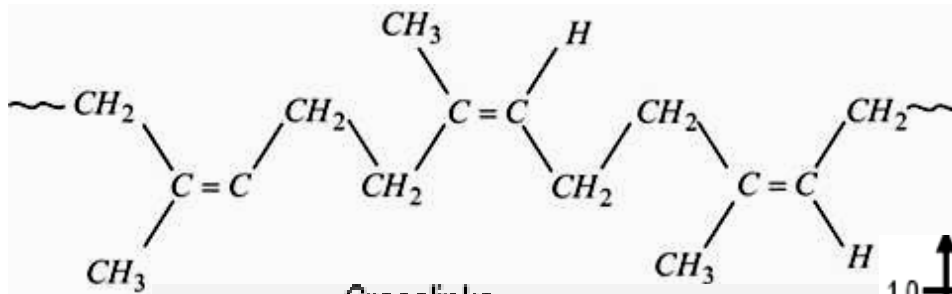
fotorezyst negatywny:

fotosensybilizator –

**2,6-bis(4-azydobenzal)-4-metylocykloheksanon**

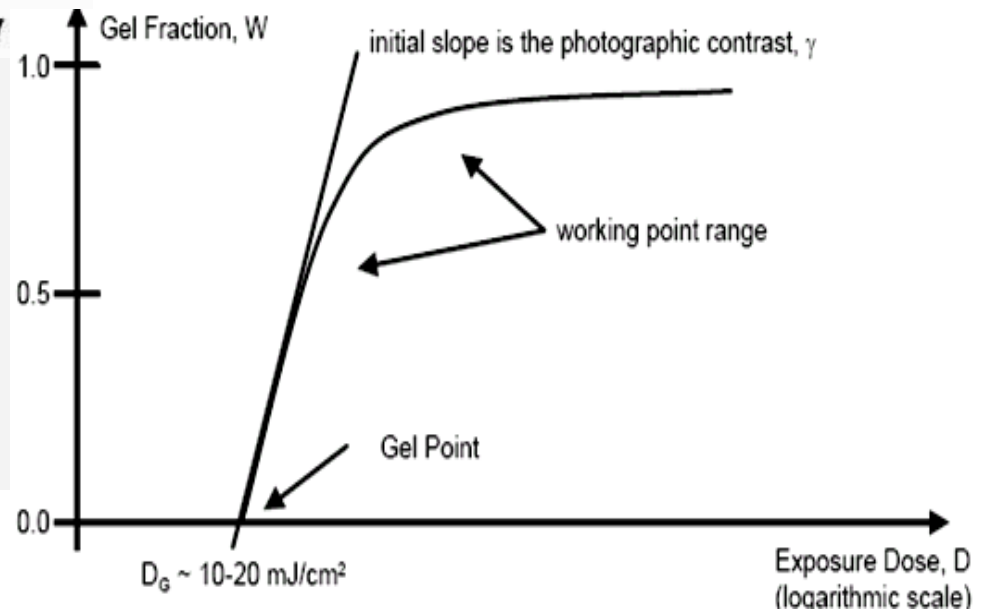


bis-rodniki nitryne inicjatorami sieciowania



wada – pęcznienie się usieciowanego

- dobra adhezja
- bdb czułość foto
- rozdzielczość ~3 mkm

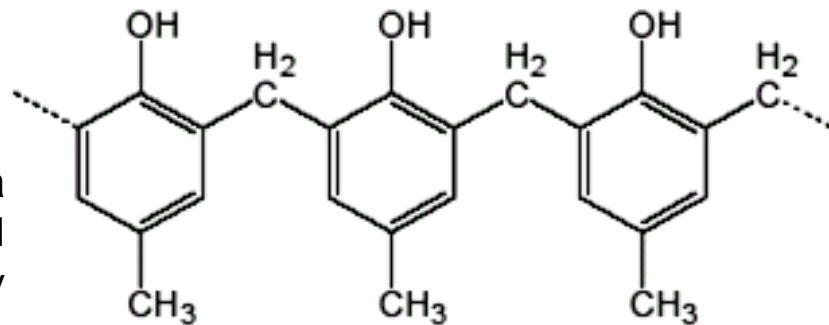




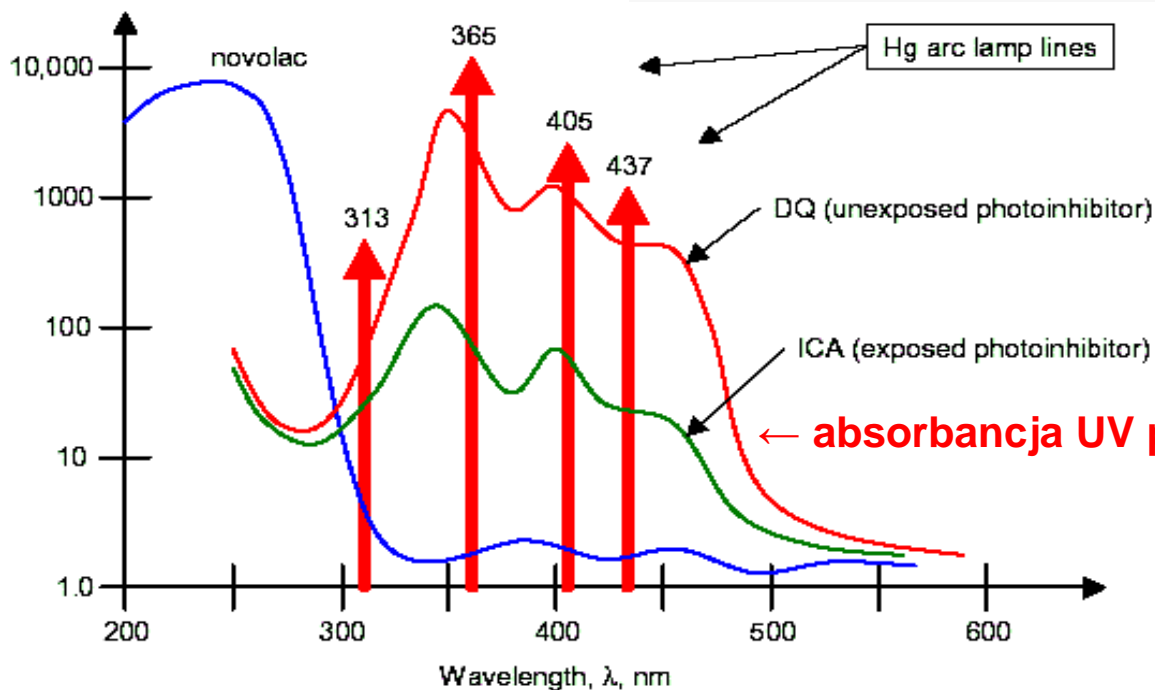
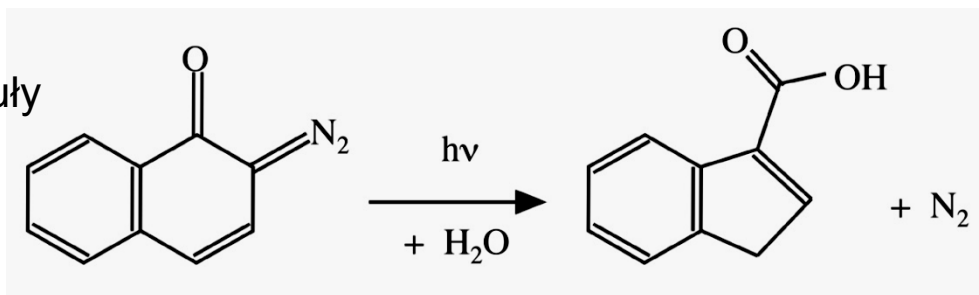
fotorezyst pozytywny:

żywica krezolowo-formaldehdowa

1000 - 3000 g/mol  
+ ksylen, octan butylowy



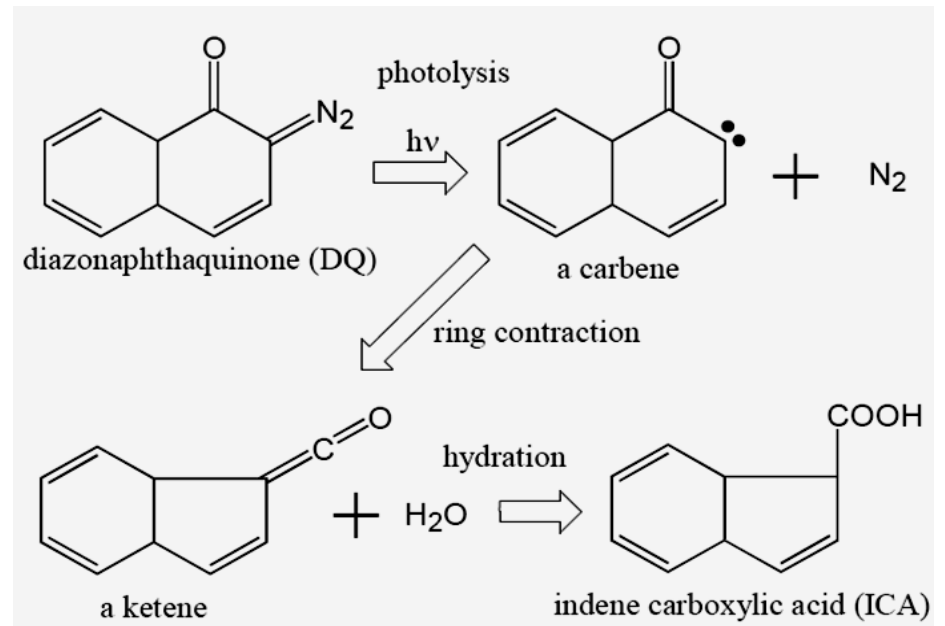
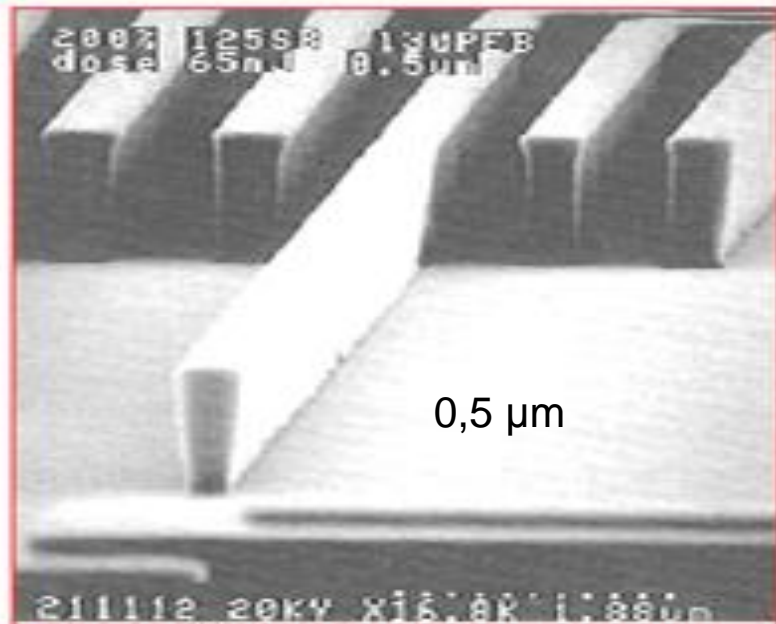
diazanaftochinon – fotoczuły  
inhibitor rozpuszczania się



wywołanie –  
wodny roztwór alkaliczny  
(~0,15 M KOH)

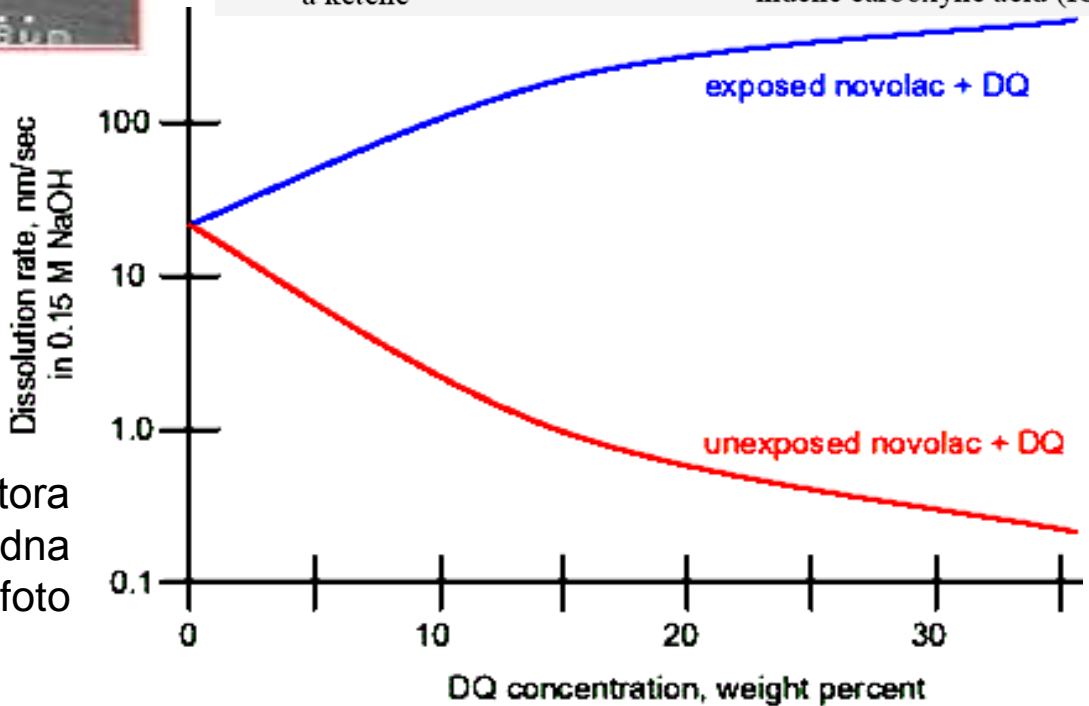
← absorbanca UV pasuje do emisji lampy Hg

żywica aromatyczna →  
odporna na obróbkę plazmową

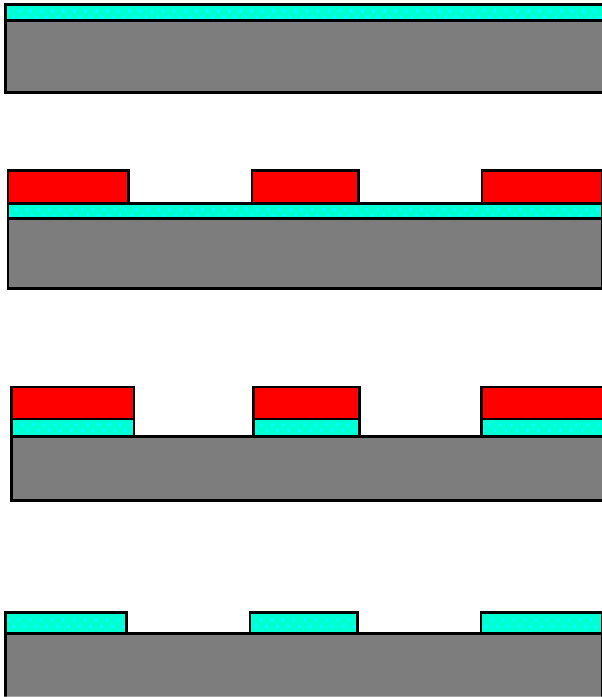


nie występuje pęcznienie  
 → **bdb rozdzielczość**

wysoka zawartość sensybilizatora  
 → duża dawka UV niezbędna  
 → **niska wydajność** foto

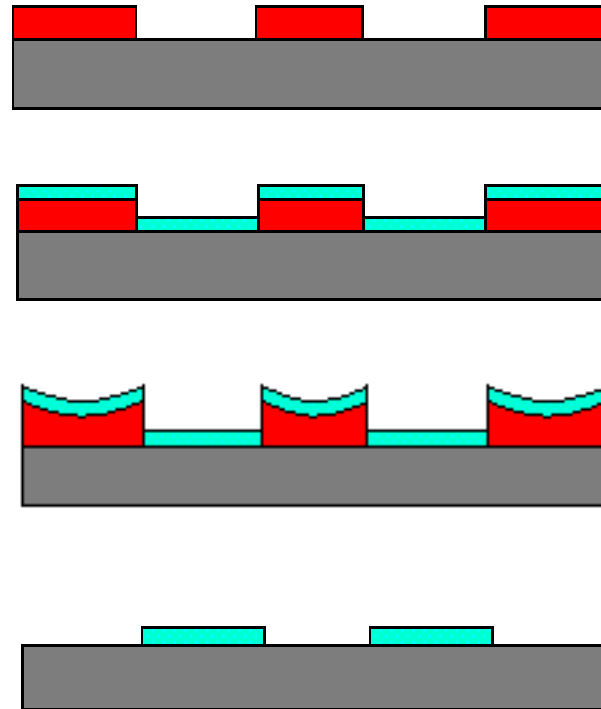


## etch back

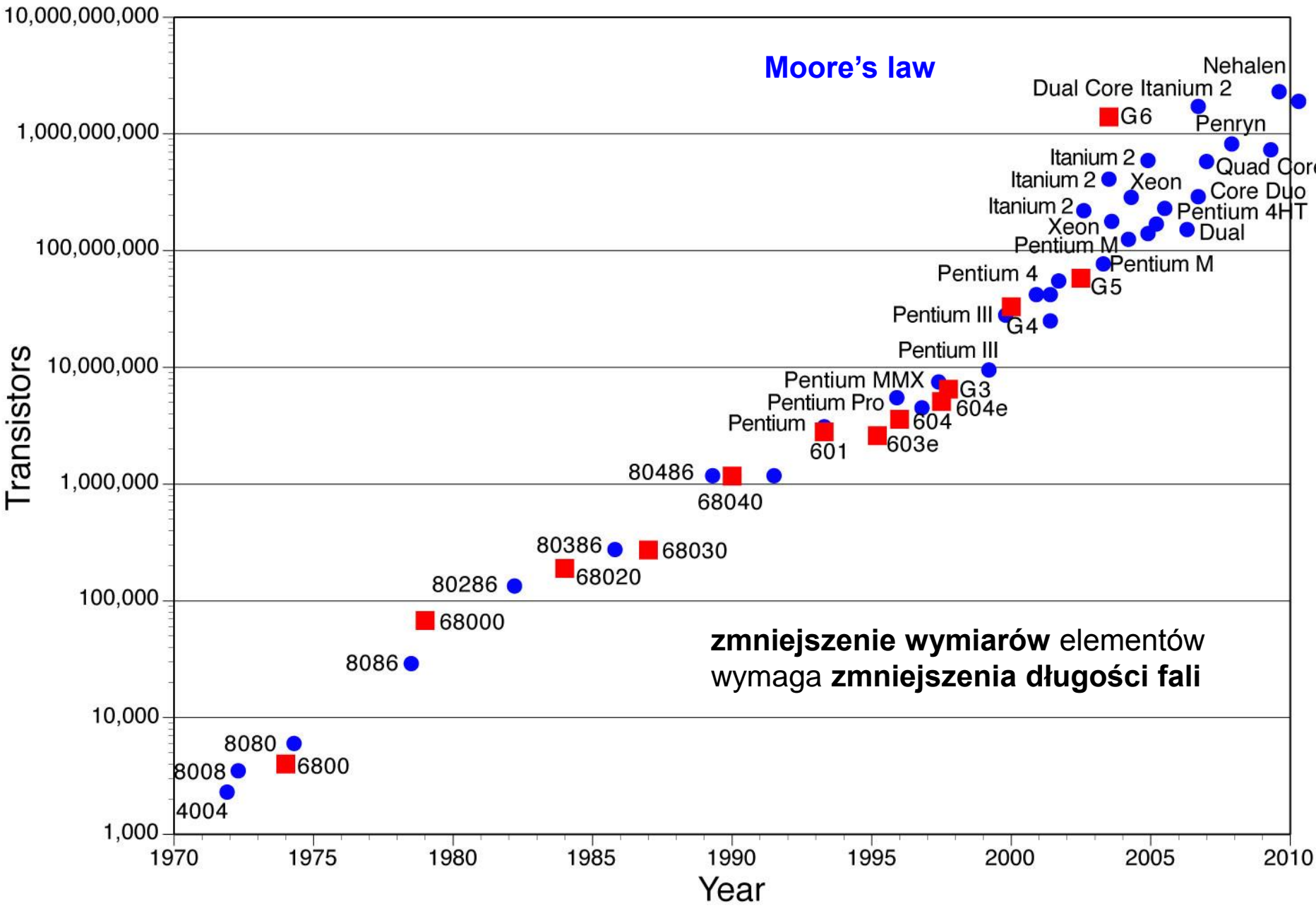


**warstwa Al** trawiona  
w oknach **fotorezystu**

## lift-off



**fotorezyst** pęcznieje →  
usuwa **warstwę Al**



## Mercury Arc Lamp UV and Visible Emission Spectrum

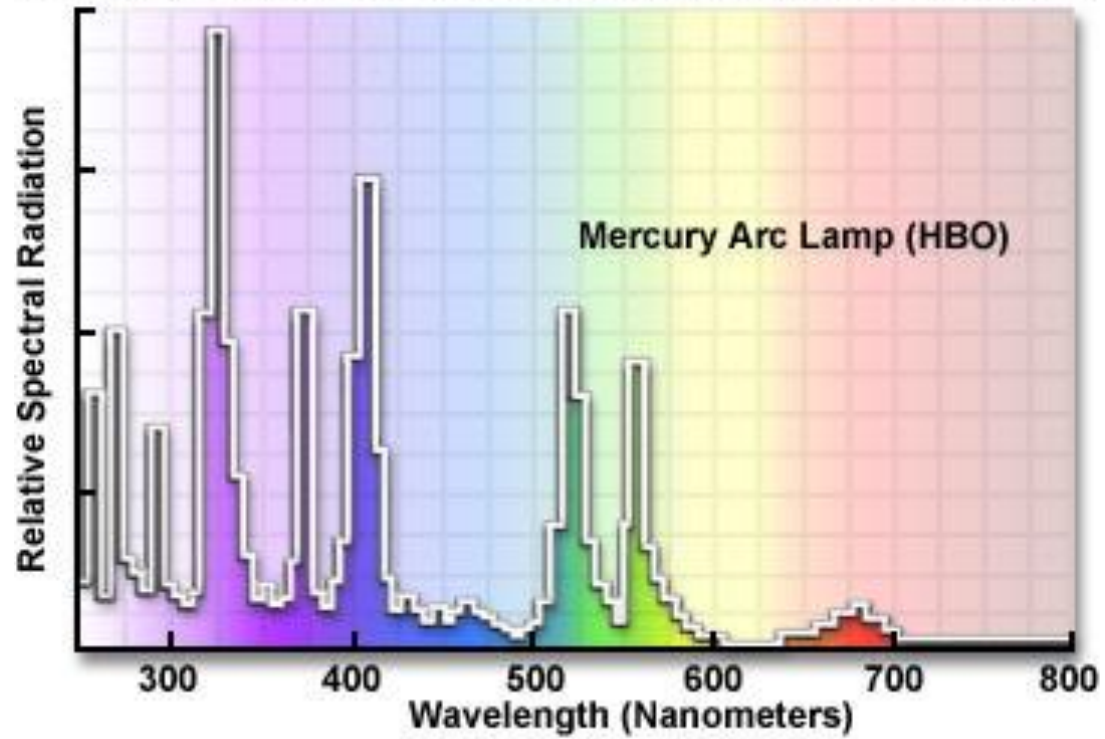


Figure 2

**h-linia 405 nm**

**i-linia 365 nm**

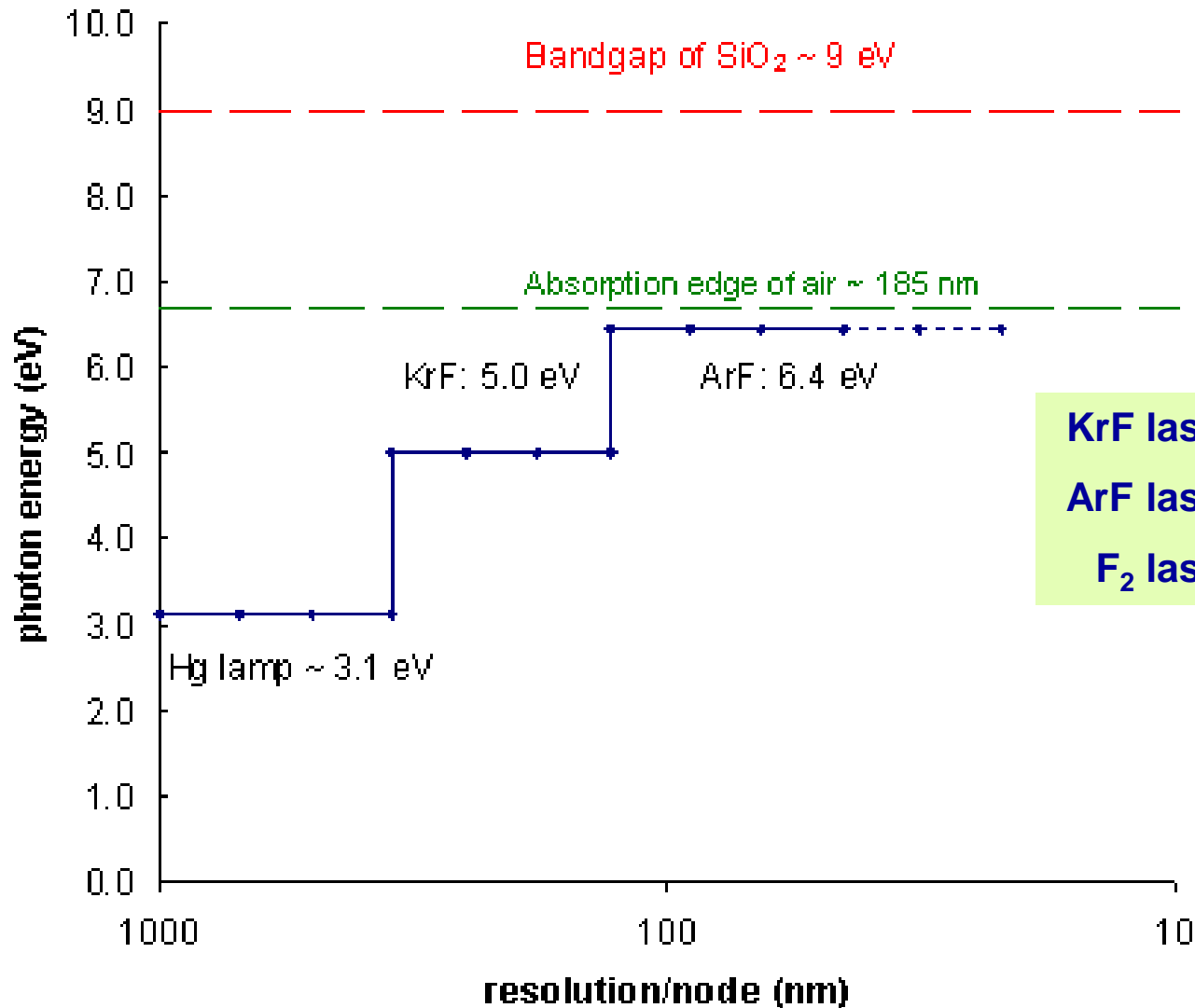
źródło napromieniowania UV:

➤ **lampka Hg**

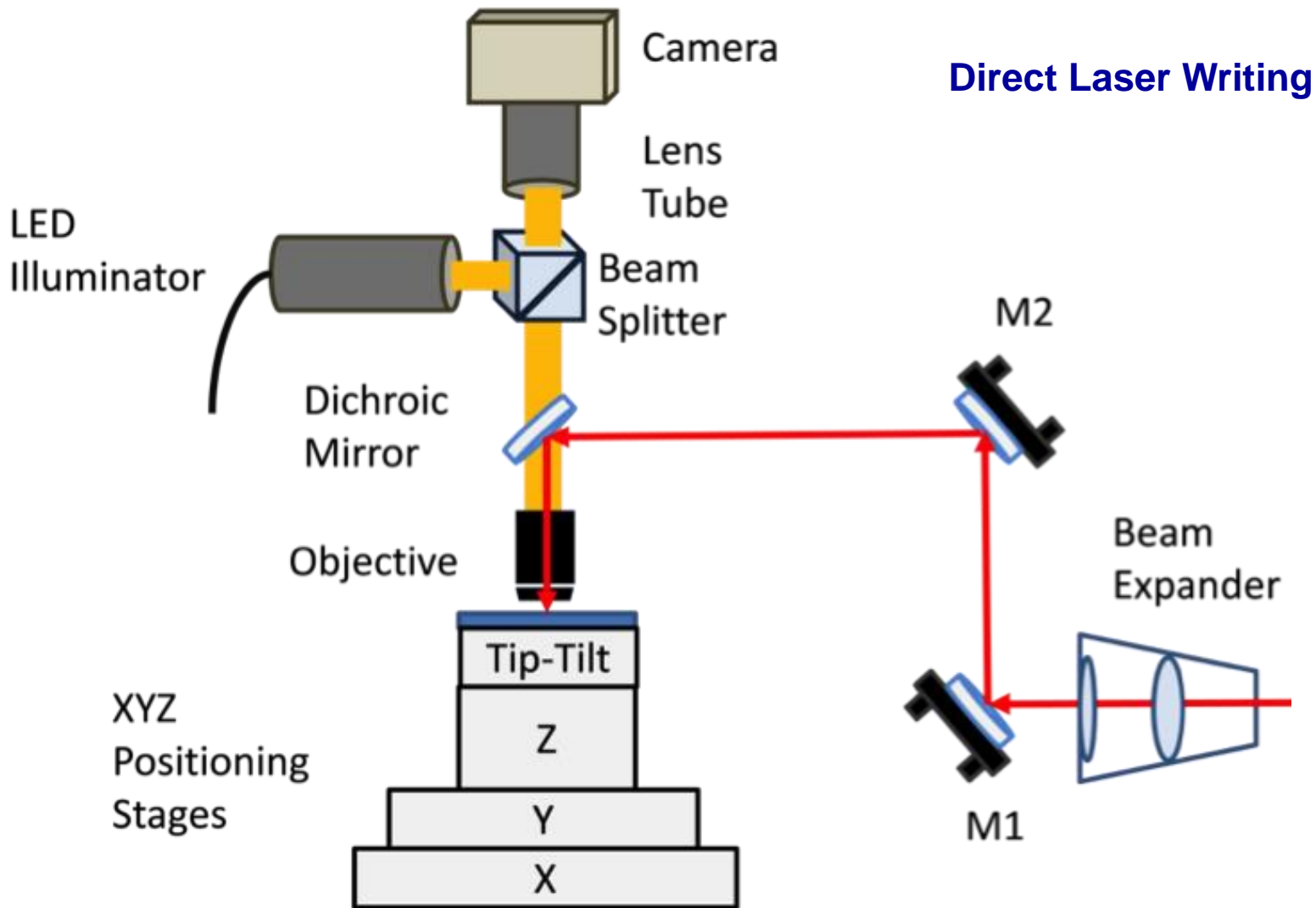


źródło UV:

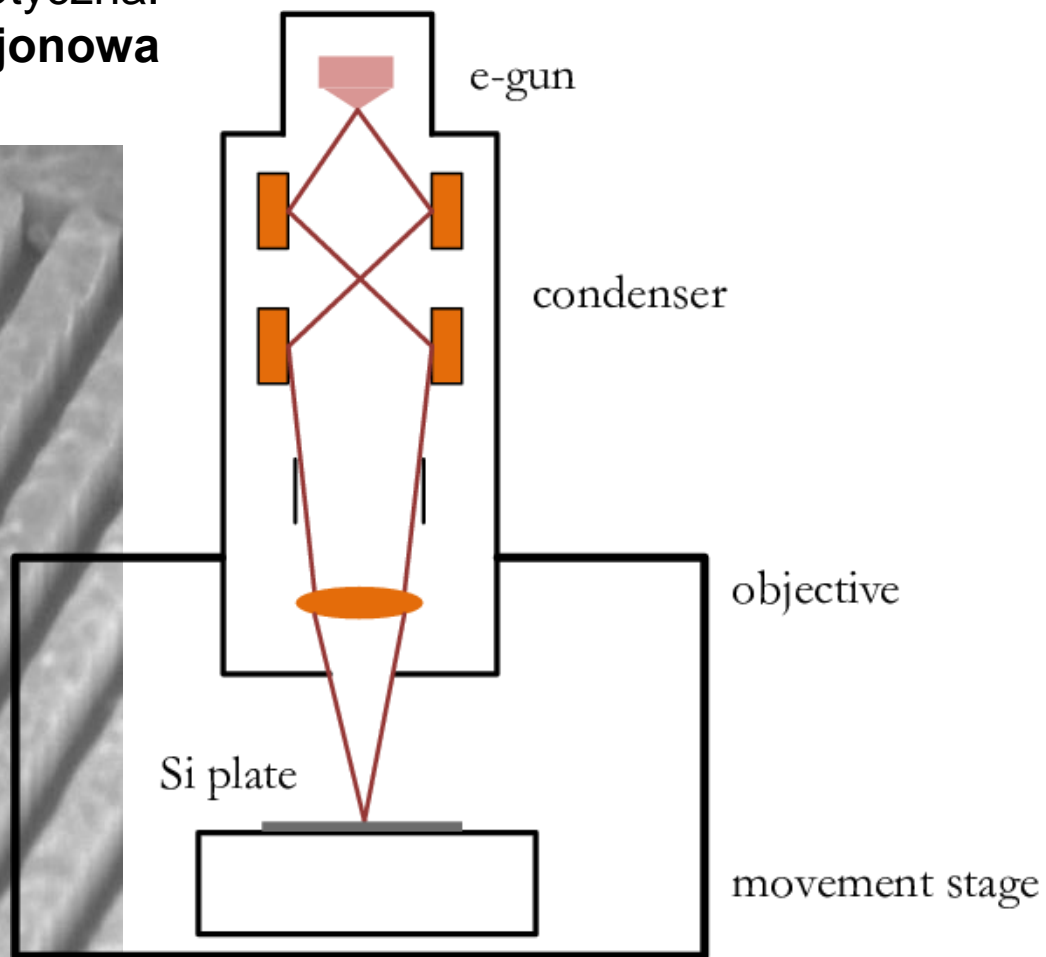
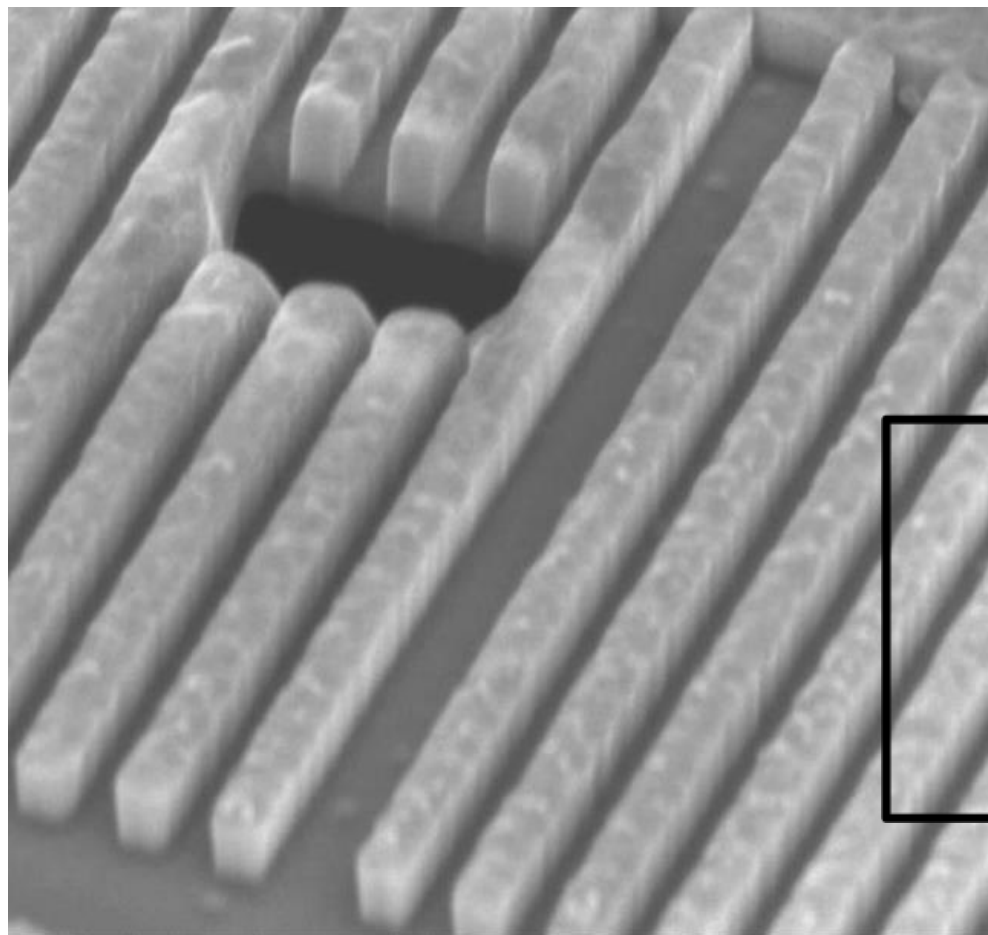
➤ laser excimerowy



KrF laser	248 nm	500 J/s
ArF laser	193 nm	80 J/s
F <sub>2</sub> laser	157 nm	0,06 J/s

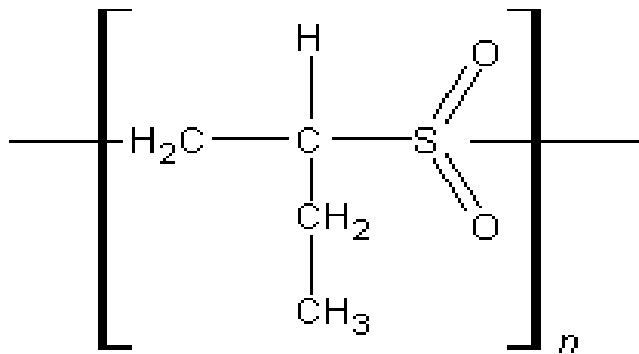


litografia post-optyczna:  
wiązka elektronowa / jonowa



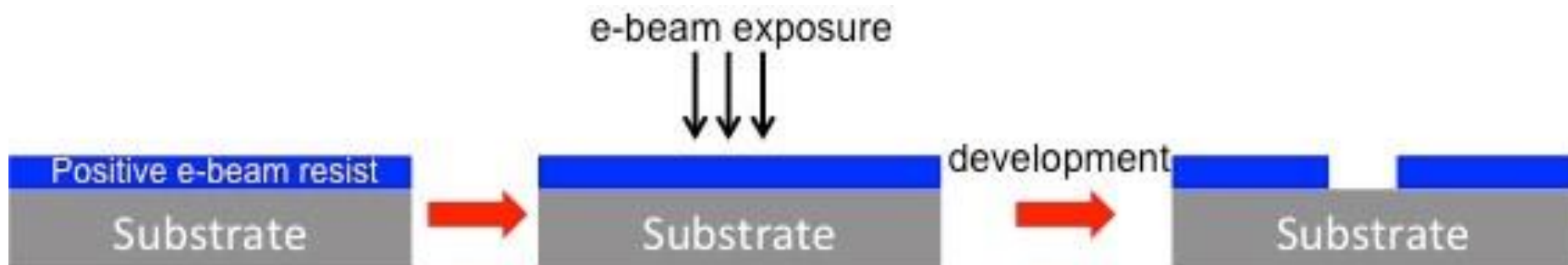
HV	WD	mag	tilt	
5.00 kV	5.0 mm	56 951 x	52 °	
500 nm				
NanoFabLab				

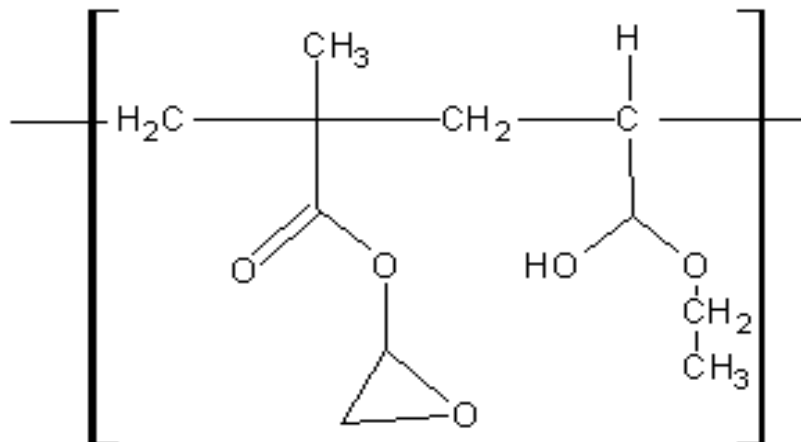




fotorezyst **pozytywny**: polibuten-1-sulfon

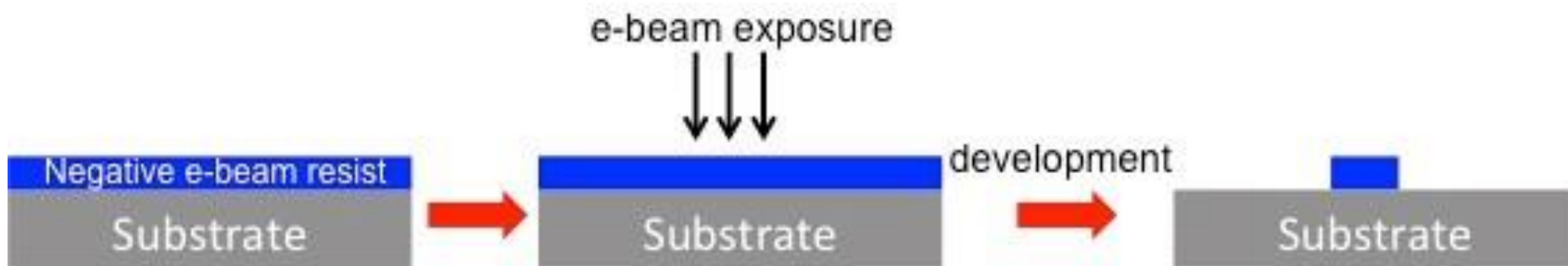
strumień elektronów → pękanie makrocząsteczek → rozpuszczalne oligomery





fotorezyst **negatywny**:  
kopolimer metakrylanu glicydydu i akrylanu etylu

polimeryzacja anionowa grup glicydylowych → sieciowanie



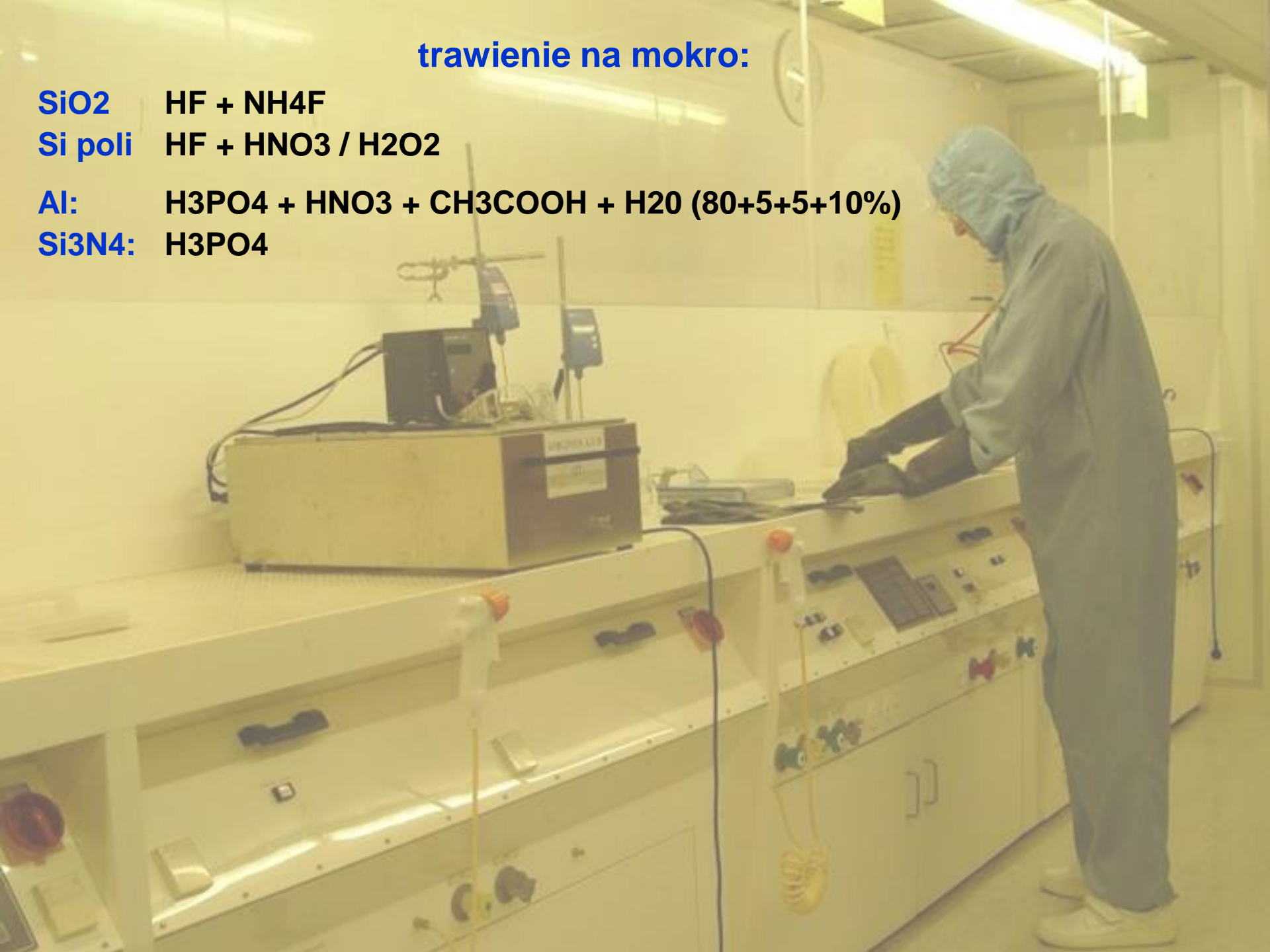
## trawienie na mokro:

**SiO<sub>2</sub>** HF + NH<sub>4</sub>F

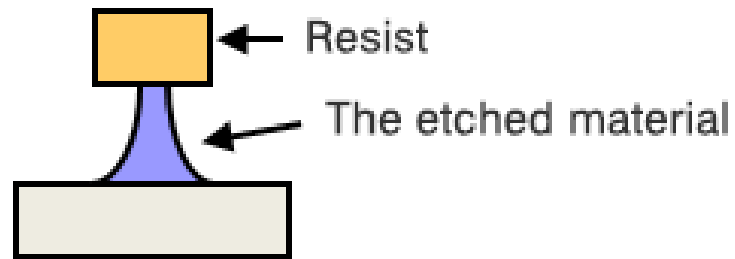
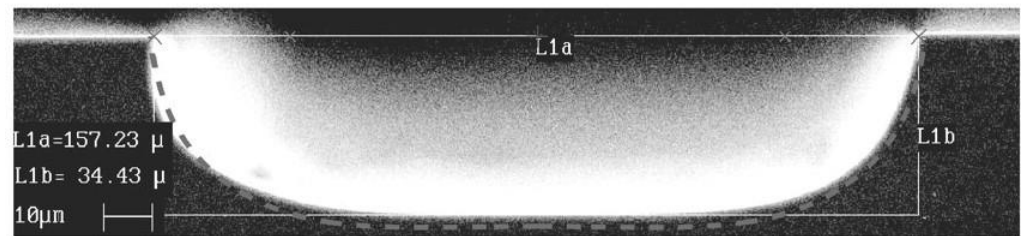
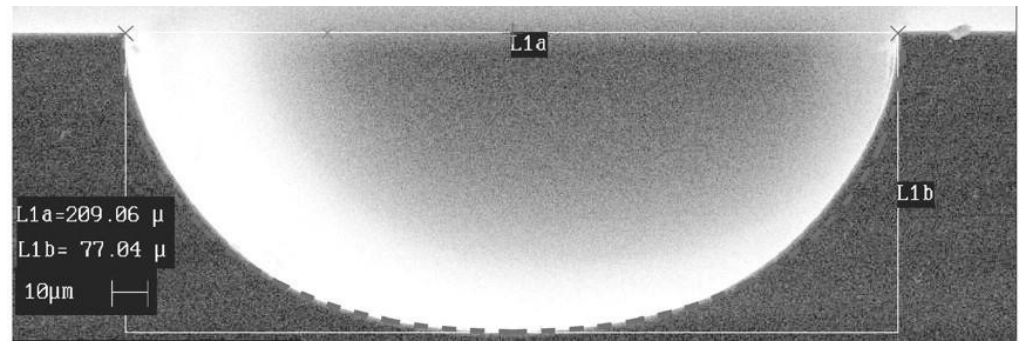
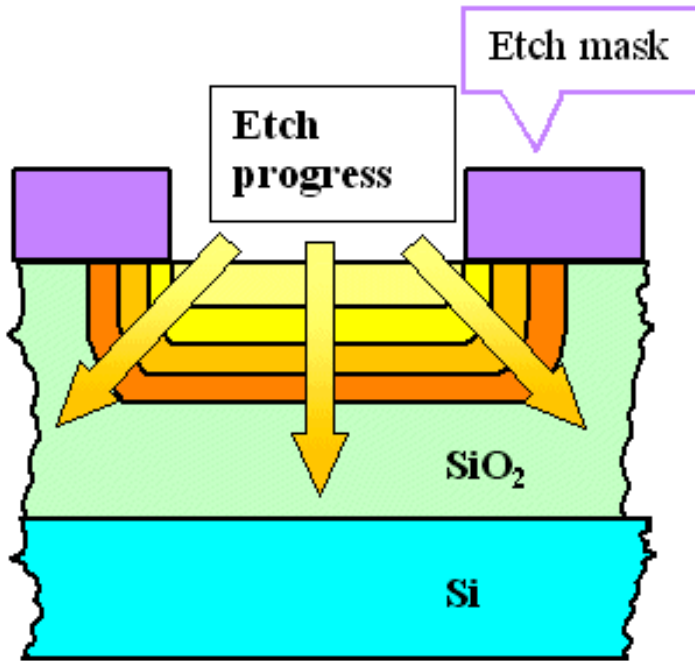
**Si poli** HF + HNO<sub>3</sub> / H<sub>2</sub>O<sub>2</sub>

**Al:** H<sub>3</sub>PO<sub>4</sub> + HNO<sub>3</sub> + CH<sub>3</sub>COOH + H<sub>2</sub>O (80+5+5+10%)

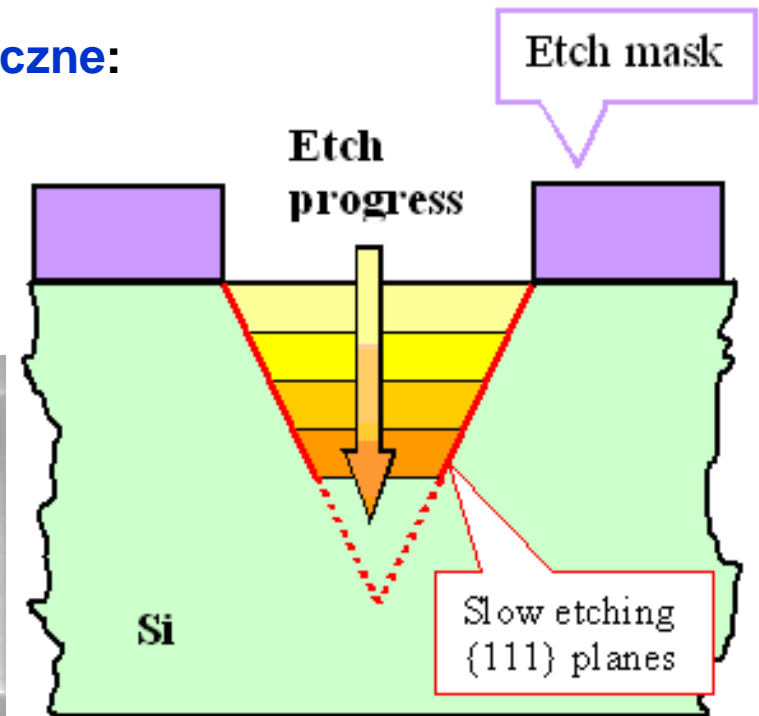
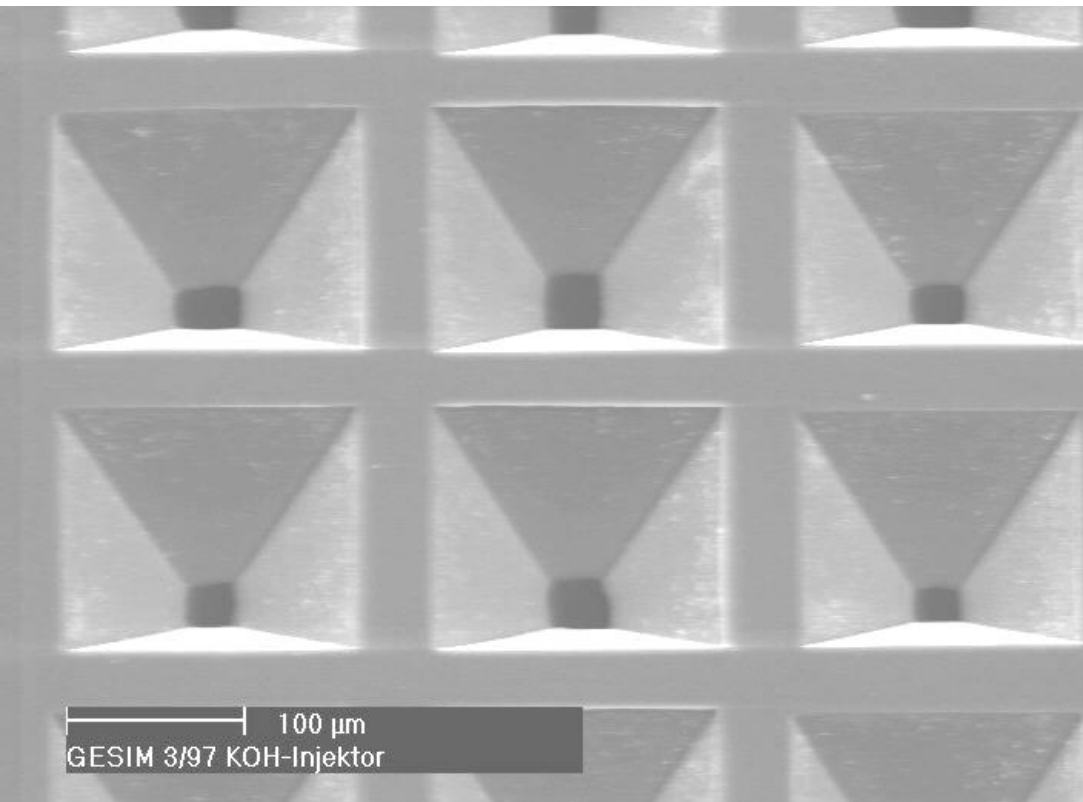
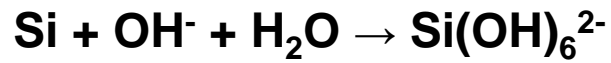
**Si<sub>3</sub>N<sub>4</sub>:** H<sub>3</sub>PO<sub>4</sub>



# trawienie na mokro – izotropowe



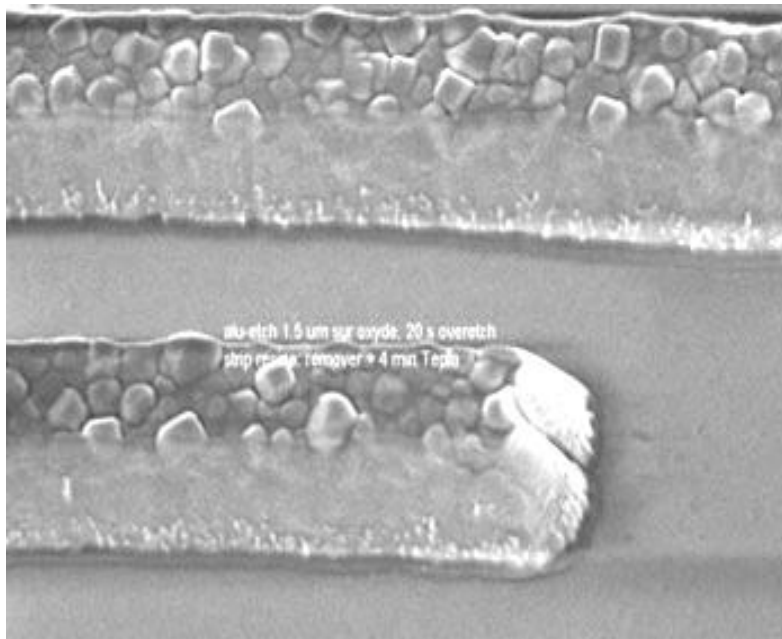
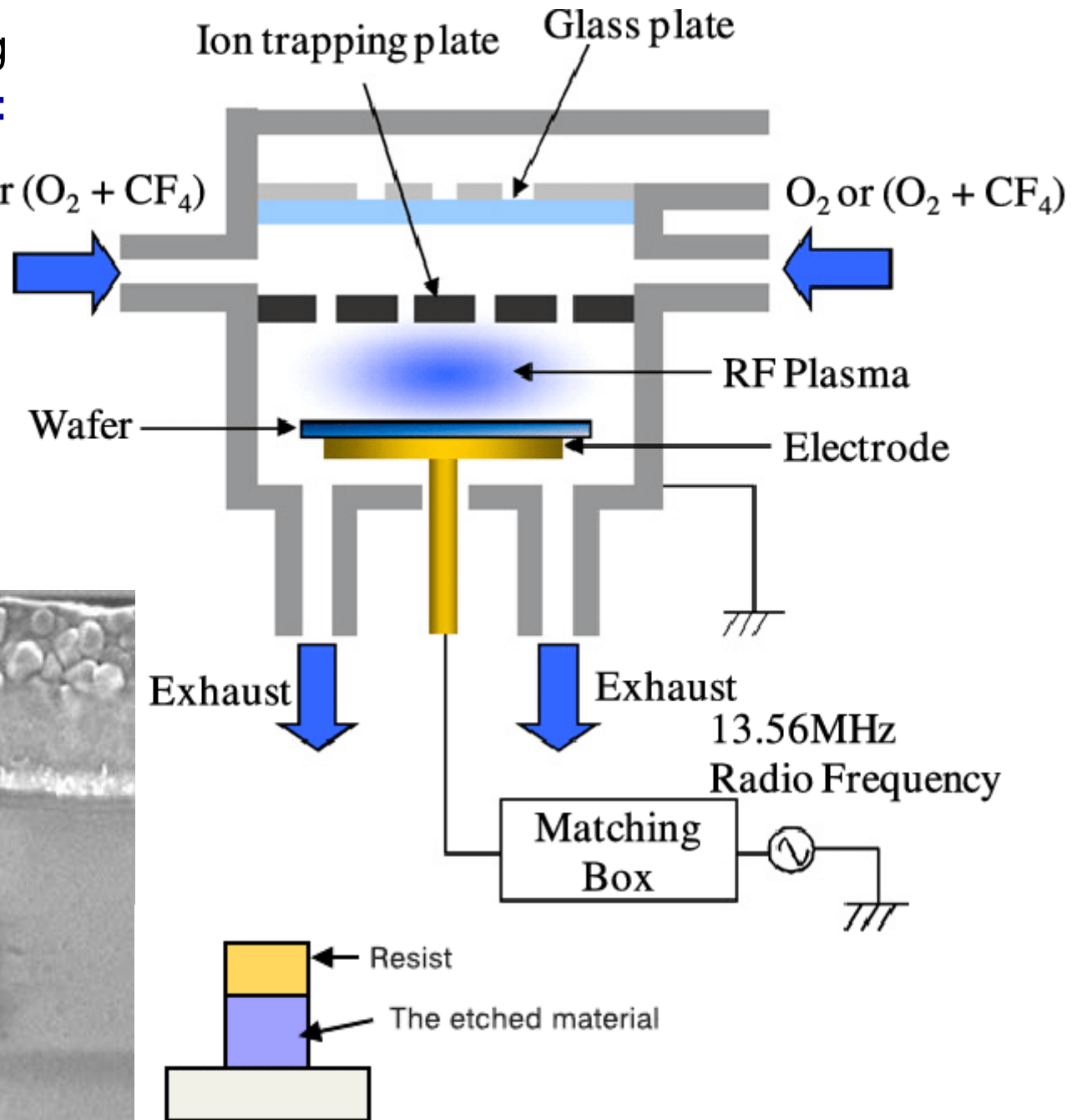
**Si mono: anizotropowe trawienie alkaliczne:**



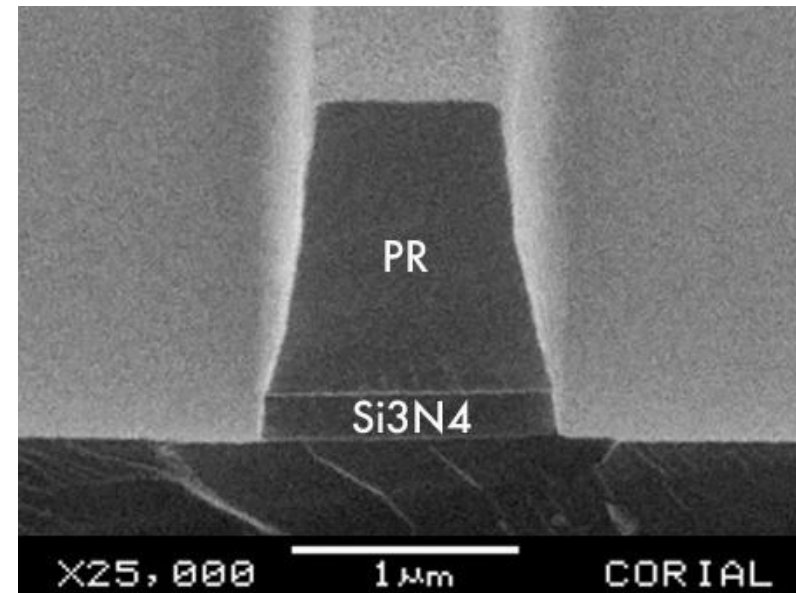
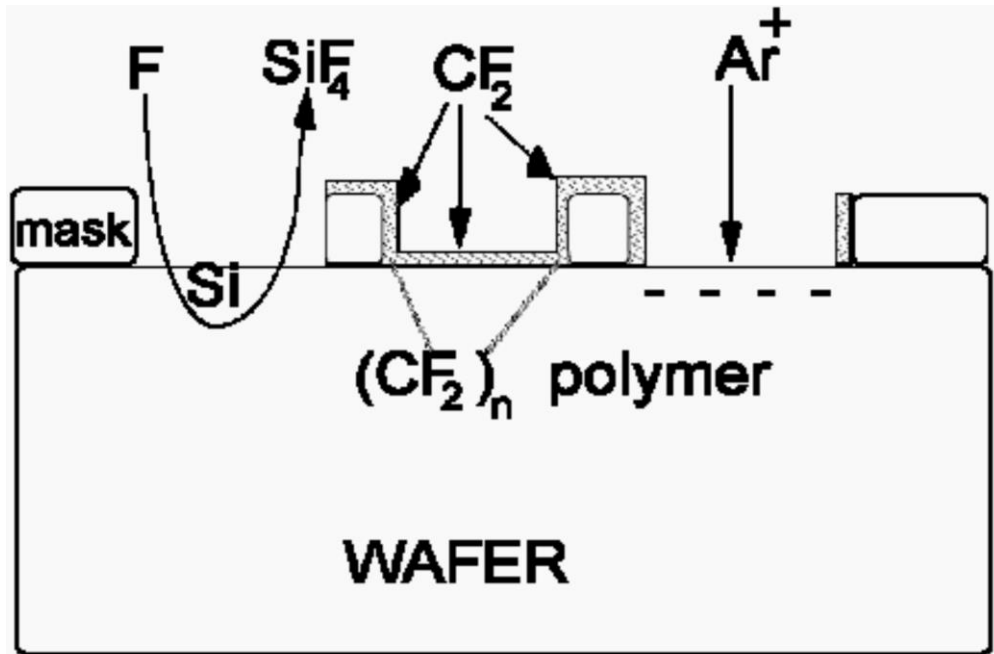
- ✓  $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}_2$
- ✓  $(\text{CH}_3)_4\text{N}^+\text{OH}^-$
- ✓  $\text{H}_2\text{N}-\text{NH}_2$
- ✓ KOH

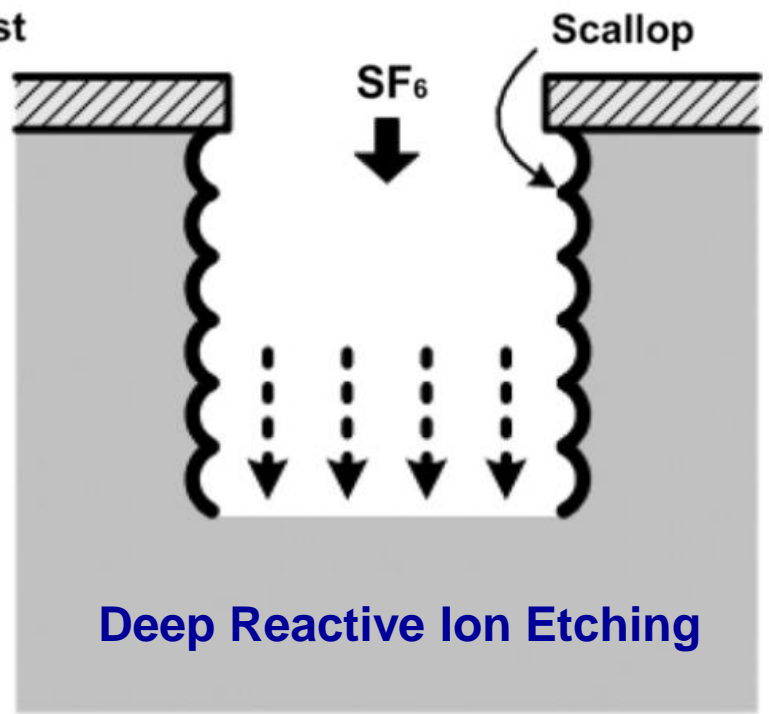
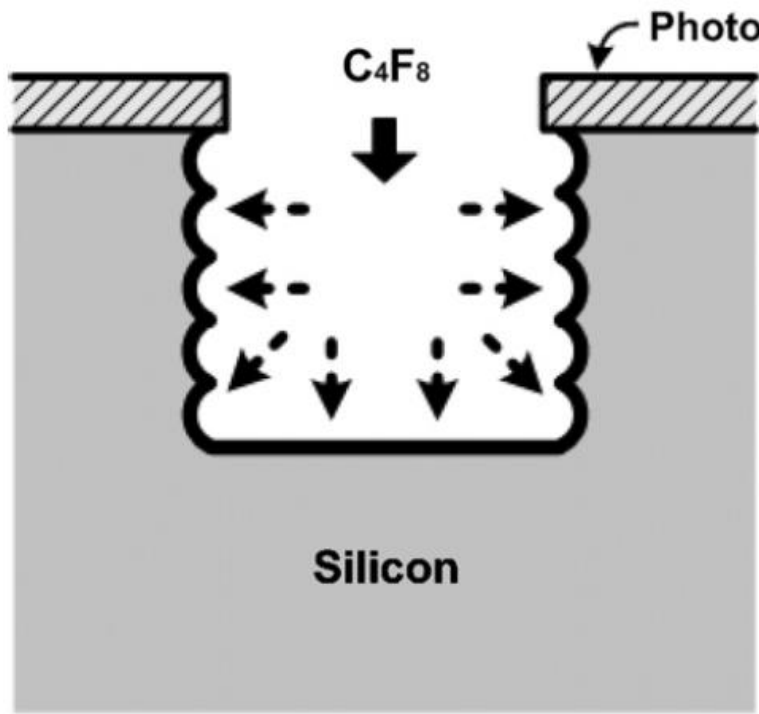
dry etching  
trawienie plazmowe:

dotatki reaktywne:  
**SF<sub>6</sub>**, F<sub>2</sub>, Cl<sub>2</sub>, BCl<sub>3</sub>



- trawienie Si, Si<sub>3</sub>N<sub>4</sub>: Ar<sup>+</sup> plazma
- wspomaganie F• + Si → SiF<sub>4</sub>
- CF<sub>4</sub> → •CF<sub>2</sub>• + F• + F•
- •CF<sub>2</sub>• rodniki ulegają polimeryzacji na powierzchni → (CF<sub>2</sub>)<sub>n</sub>
- PTFE odporny do rodników F• lecz degraduje pod Ar<sup>+</sup>  
→ **wysoka anizotropia trawienia**





Deep Reactive Ion Etching

