

EPL masks

- Performance and issues -

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1. Introduction

2. 8 in. EPL stencil masks

- **Development status and performance**

3. EPL membrane masks

- **Development status and performance**

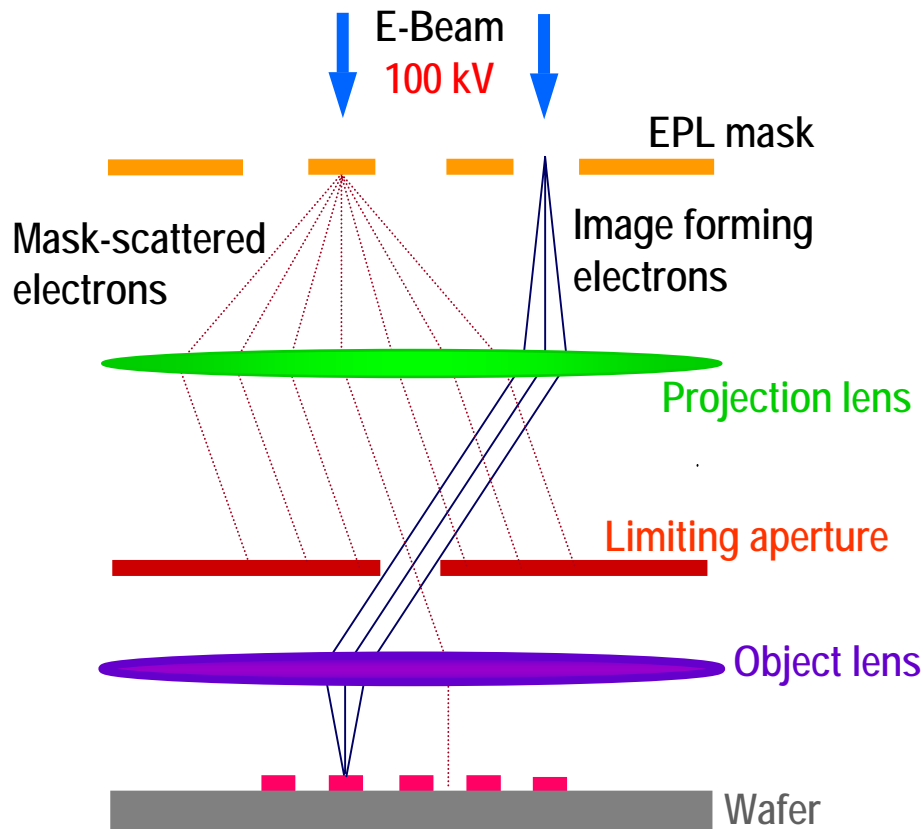
4. Evolution of EPL masks

- **EPL stencil mask for 45-nm node and beyond**
- **High-performance EPL membrane mask**

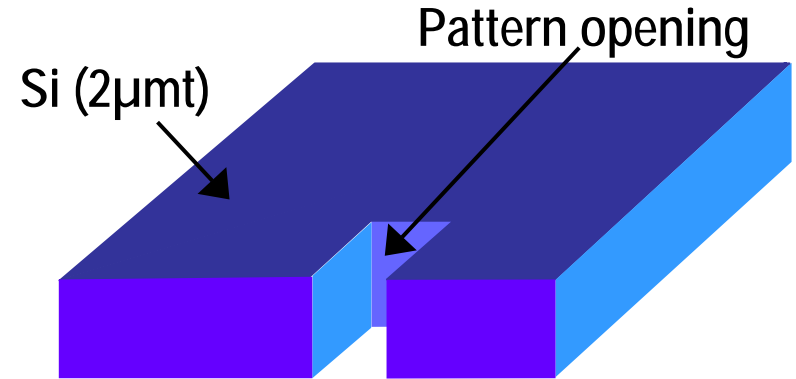
5. Technical issues

6. Summary

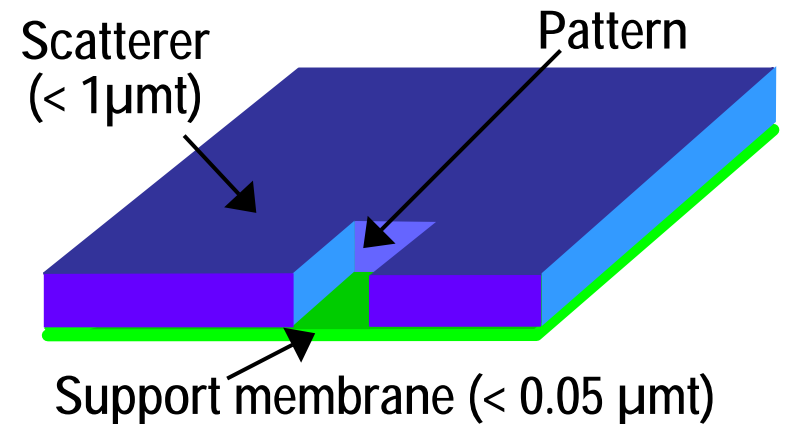
Electron optics



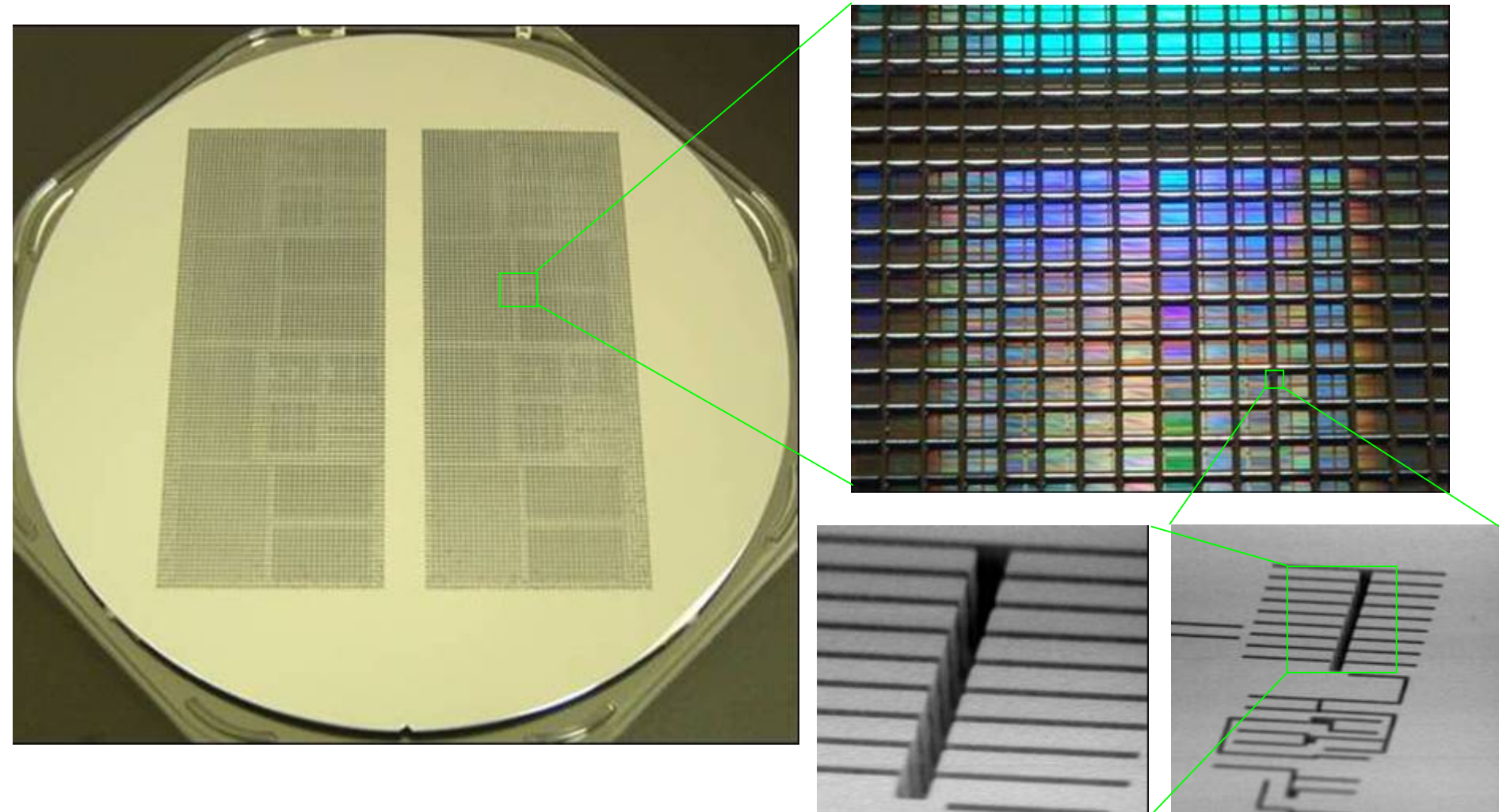
Si stencil mask



Membrane mask



8 in. EPL stencil mask with complementary 70-nm-rule SoC device patterns



Performance comparison of EPL mask substrates

New substrate



SOI wafer



Thickness and Intrinsic stress

Si membrane : 1.00 μ m-thick, **0-10MPa**

CrNx stopper : 0.10 μ m-thick, **+/-10MPa**

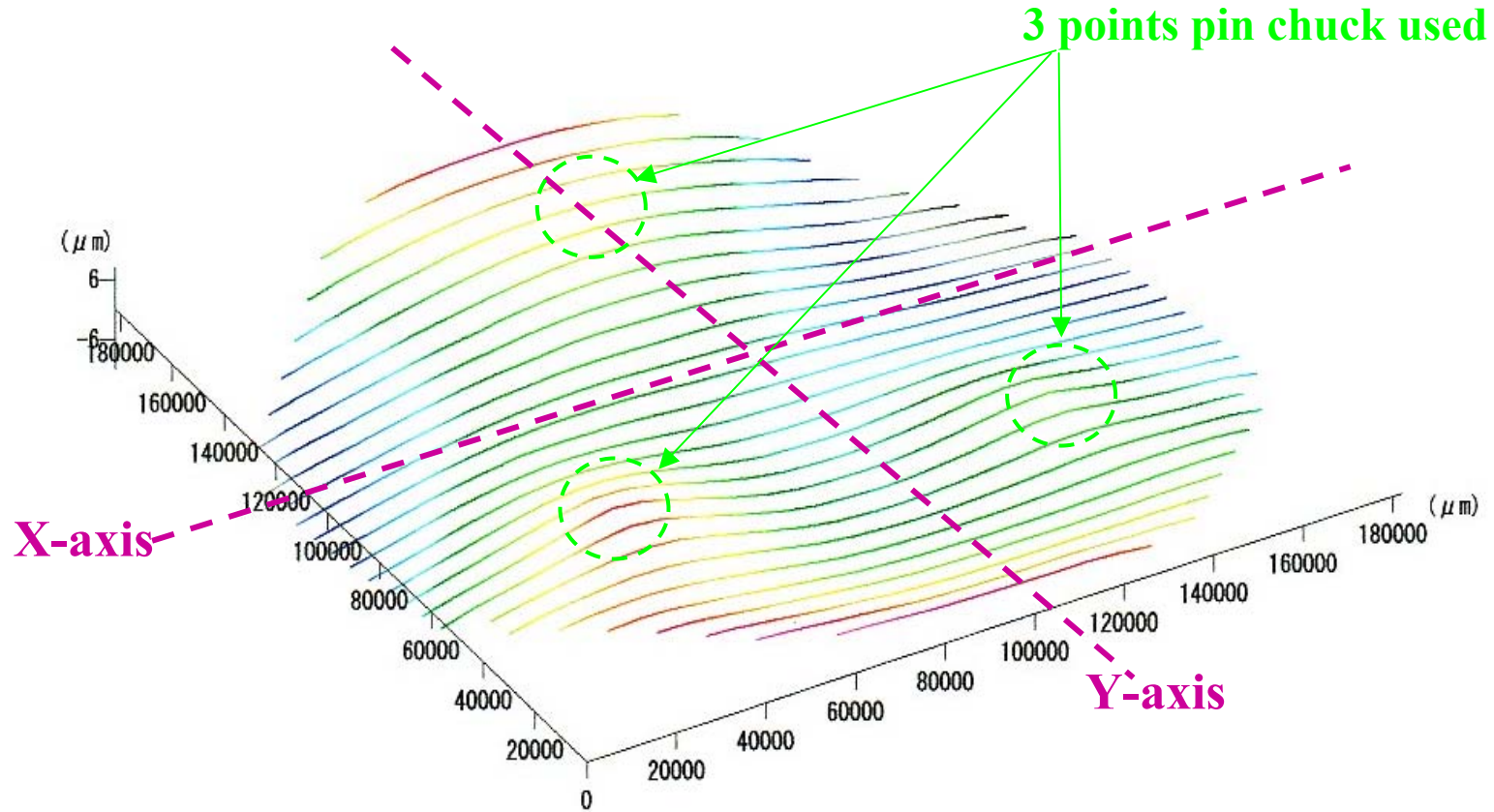
Thickness and Intrinsic stress

Si membrane : 1.00 μ m-thick, **≥ 100 MPa**

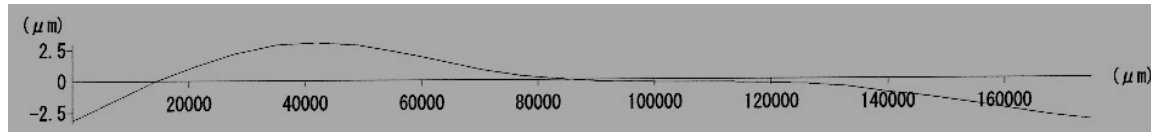
SiO₂ stopper : 0.30 μ m-thick, **≥ -500 MPa**

Items	New substrate	Conventional SOI
Structure	Si / CrNx / Si	Si / SiO ₂ / Si
Thickness (μ m)	2.0 / 0.1 / 725	2.0 / 1.0 / 725
Membrane distortion control in mask fabrication process	Good	Bad
Etching selectivity (Dry etch)	> 3000 (Si / CrNx)	< 300 (Si / SiO₂)
Etching selectivity (Wet etch)	> 10000 (Si / CrNx)	< 1000 (Si / SiO₂)

Evaluation of an 8 in. mask flatness

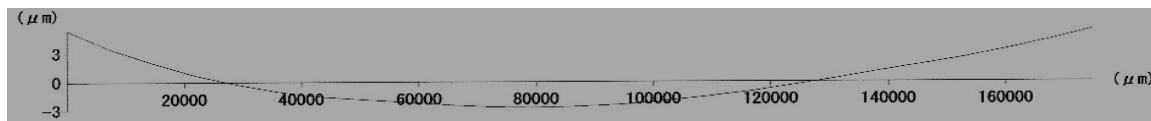


X-axis



6.40 μm (P_V)

Y-axis



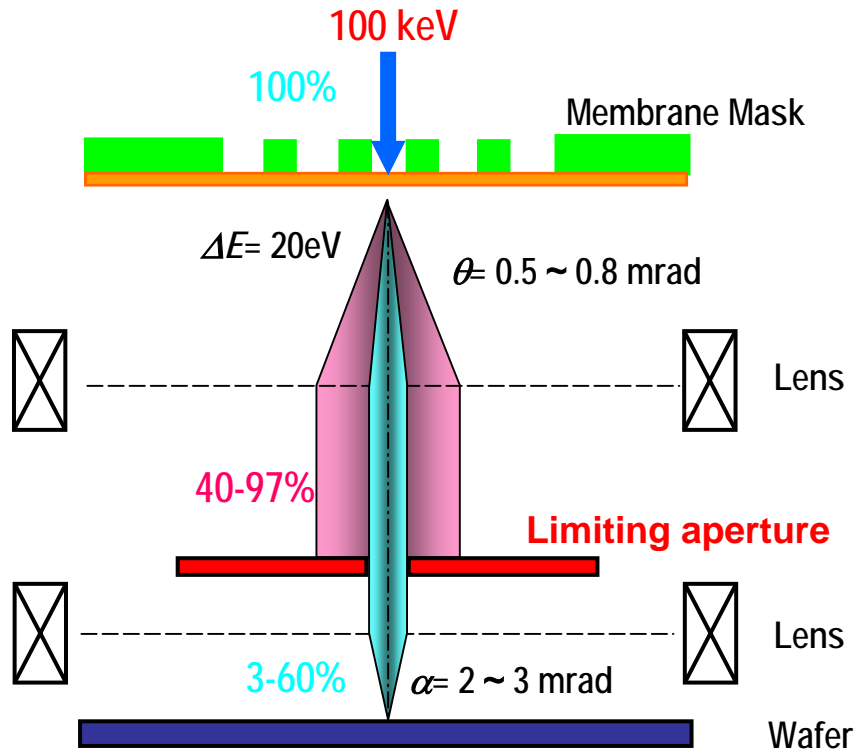
8.15 μm (P_V)

Summary of HOYA's stencil mask qualities

	Target spec. (for 65nm node)	Former qualities (2001)	Recent qualities (2003)
Pattern CD accuracy (\pm , %)	5	10 (in one SF)	7 (8 in., @280nm)
Pattern corner rounding (nm)	<45	<50	<50
Pattern image placement (nm)	11	No data	<20
Pattern LER (nm, 3σ)	3.5	<15	<10
Pattern sidewall angle (deg.)	90.0-90.2	90.0-90.5 (SF)	90-90.8 (8 in.)
Substrate flatness (μm , P_V)	10	>20	<10
Mask flatness (μm , P_V)	10	>20	<10

Concept of a new continuous EPL membrane mask

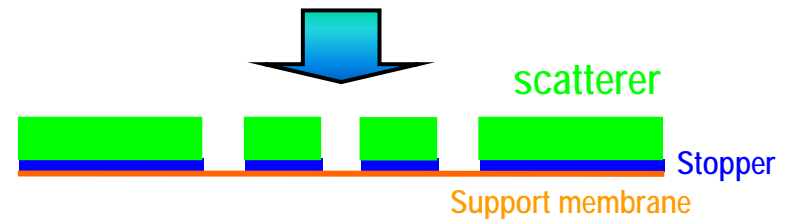
Electro-optics



Optimum structure

Membrane: the thinner the better

Scatterer : $t_s \geq 600 \text{ nm}$



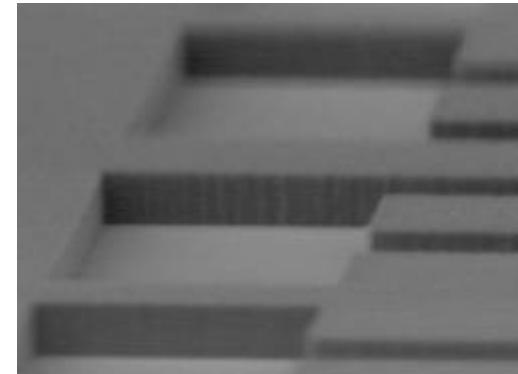
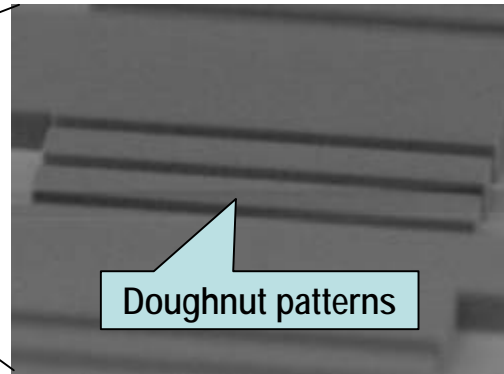
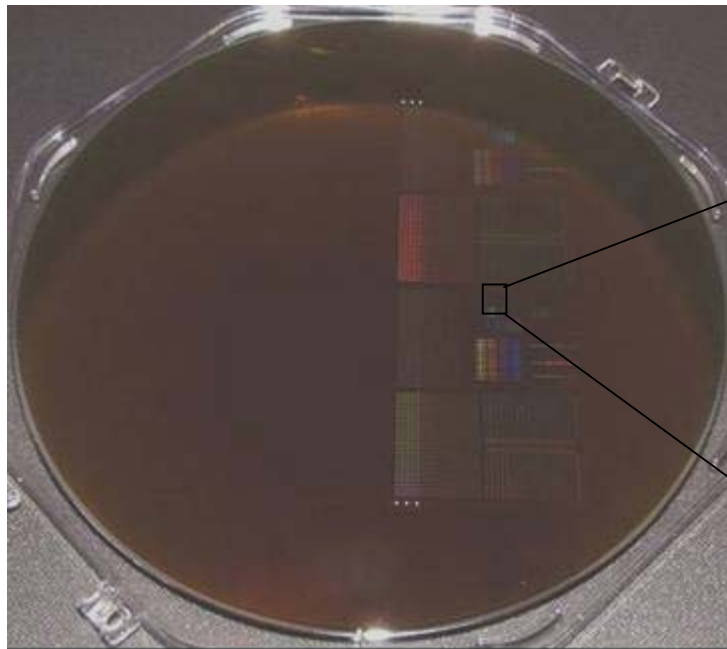
E.g. when $t_m = 30 \text{ nm}$, $t_s = 600 \text{ nm}$,
then

Transmission, $T_m = 60\%$, $T_s = 0\%$
and Contrast, $C = 100\%$

- Support membrane is made of a thin film of low density and high Young's modulus for decreasing electron scattering.
- Scatterer is composed of a thick film of low density and high Young's modulus for the scatterer self-supporting function.

EPL membrane mask (Development status)

8 in. continuous DLC membrane mask with non-complementary 70-nm-rule SoC device patterns



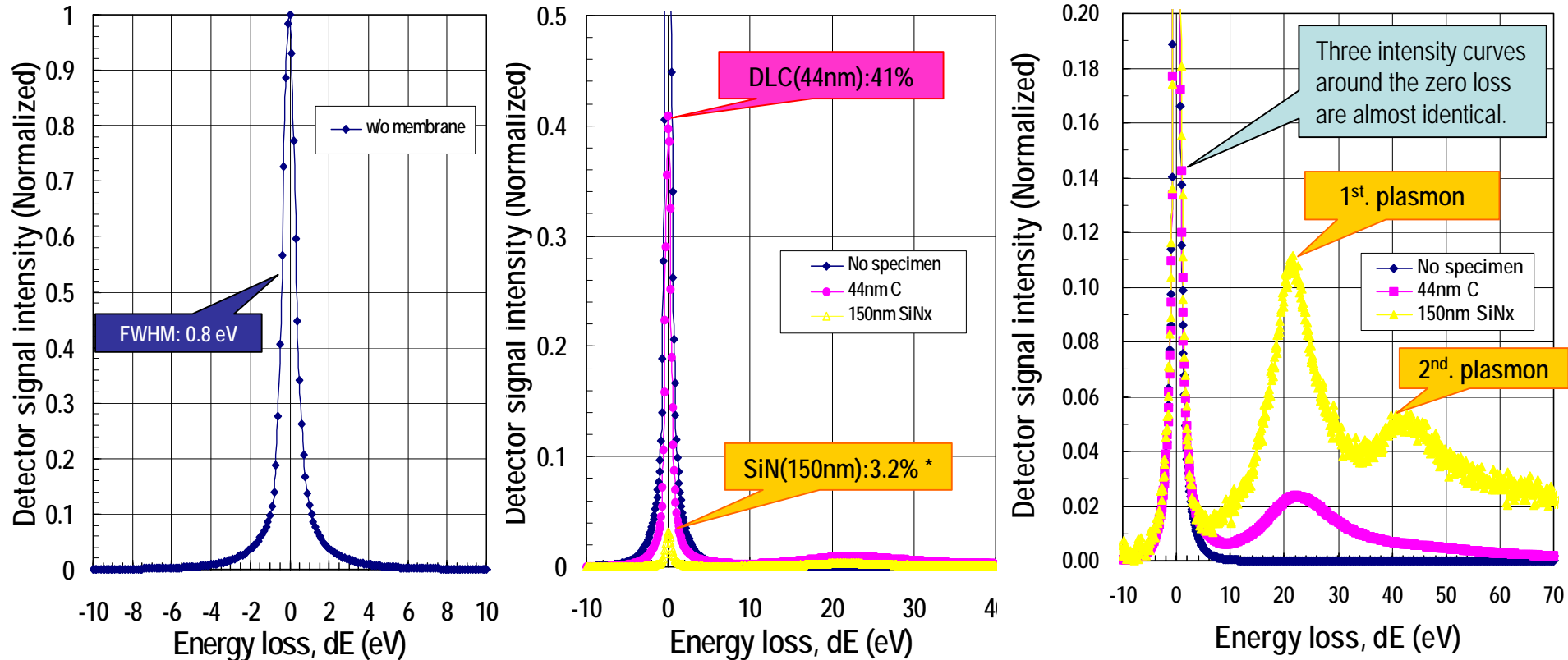
SEM photos of device patterns formed in the DLC scatterer

A fabricated 8 in. EPL continuous DLC mask

DLC scatterer thickness : 600 nm

DLC support membrane thickness : 44 nm

Energy distribution of membrane transmitted electrons measured with EADAM

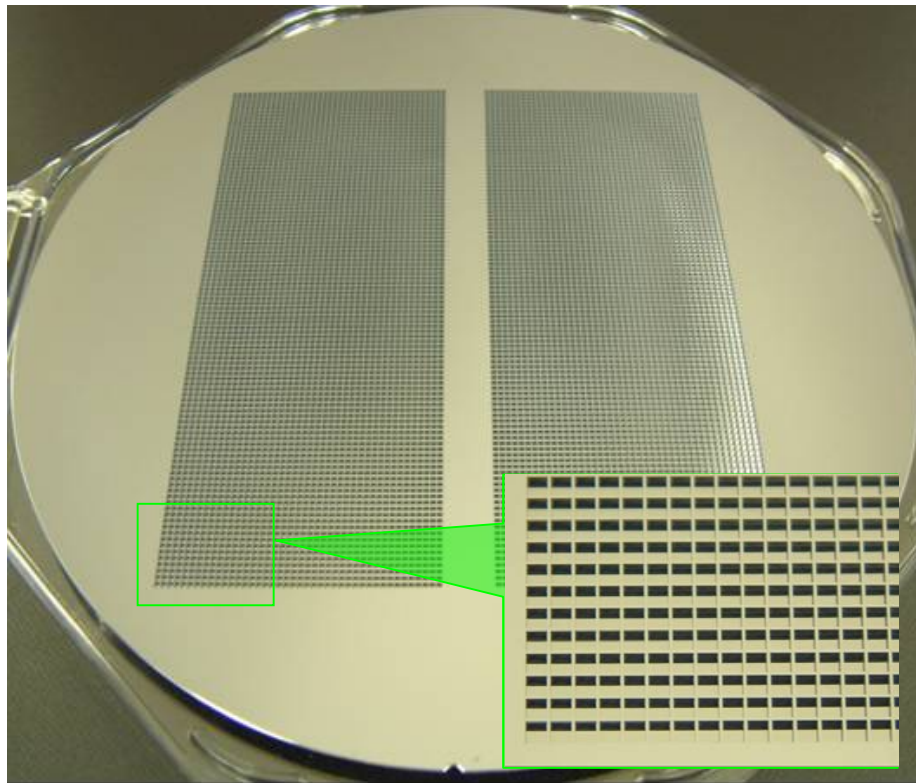


Energy distribution of irradiated electrons
(Normalized by the zero-loss peak)

Energy distribution of membrane transmitted electrons
(Normalized by zero-loss peak without specimen)

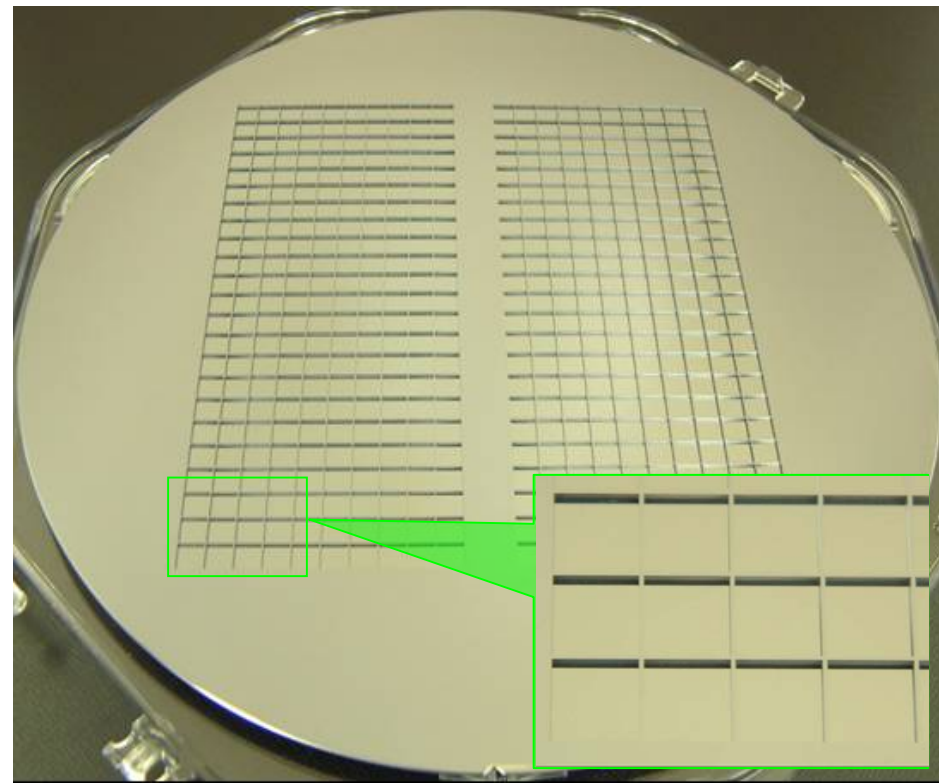
Energy distribution of membrane transmitted electrons
(Normalized by each zero-loss peak)

EPL mask blanket for 45-nm node and beyond



Conventional EPL mask blanket

- ☞ Membrane material : Silicon
- ☞ Membrane thickness : 2 μm
- ☞ SF size : 1 mm \square



Large SF EPL mask blanket

- ☞ Membrane material : Silicon
- ☞ Membrane thickness : 2 μm
- ☞ SF size : **5 mm \square**

◆ Technical issues of EPL masks

- Defect-free mask fabrication
- QTAT mask fabrication process (within 1 weeks)
- Establishment of inspection and repair systems
- Standardization of the chucking method of EB writer
- Enhancement of pattern CD and IP
- Proof of long term mask stability

- **An 8 in EPL stencil mask with complementary split patterns of 70-nm-rule SoC device has been successfully fabricated by using a newly developed mask substrate. Current status of 8 in. EPL stencil mask properties were presented.**
- **An 8 in. continuous DLC membrane mask using non-complementary 70-nm-rule SoC device patterns has been successfully fabricated by using a newly developed mask substrate.**
- **8 in. mask blanks with a large SF for 45-nm or less have been fabricated by optimizing a mask substrate basic qualities and under the strictly controlled process.**
- **High-performance 8 in. continuous DLC membrane mask with 23-nm-thick support membrane has been successfully fabricated by developing a new membrane mask fabrication process.**