PiBond

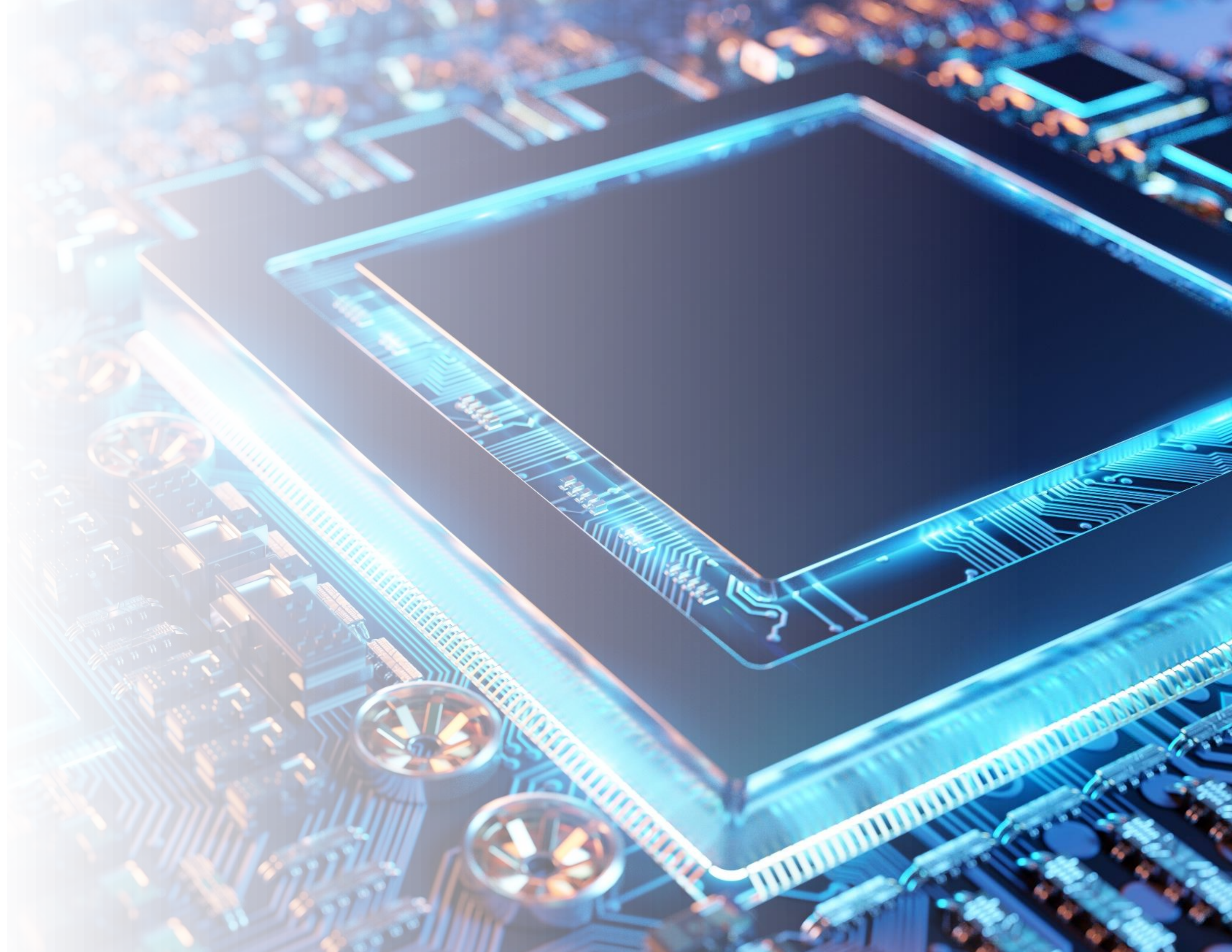
Next Generation Materials

for

Semiconductor Chips Enabling the Era of AI

and

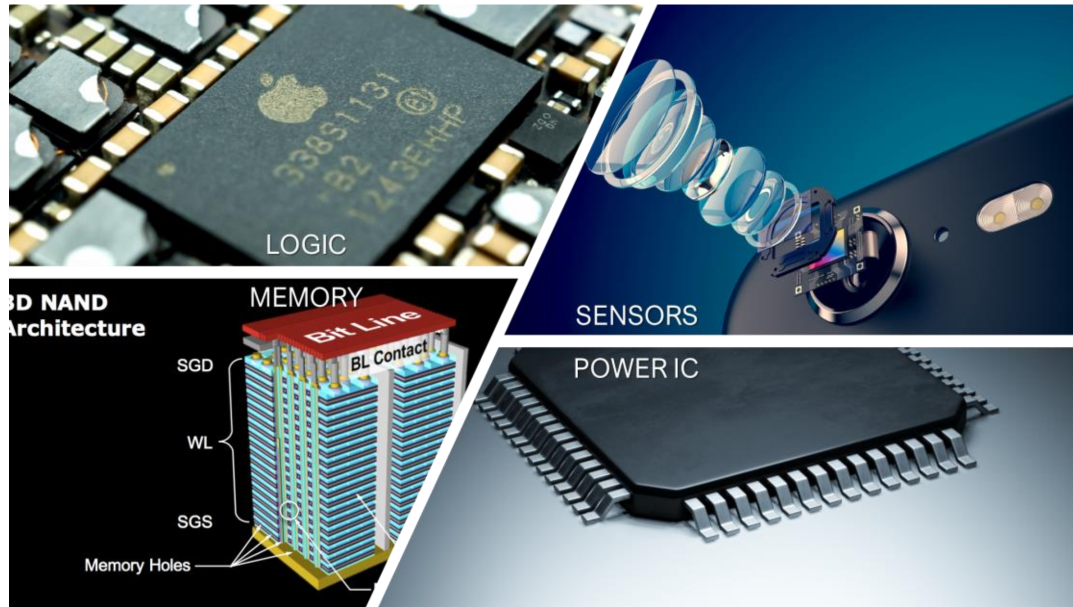
Advanced Photonic Applications



Materials and Processes for Next Generation Photonic Metastructures

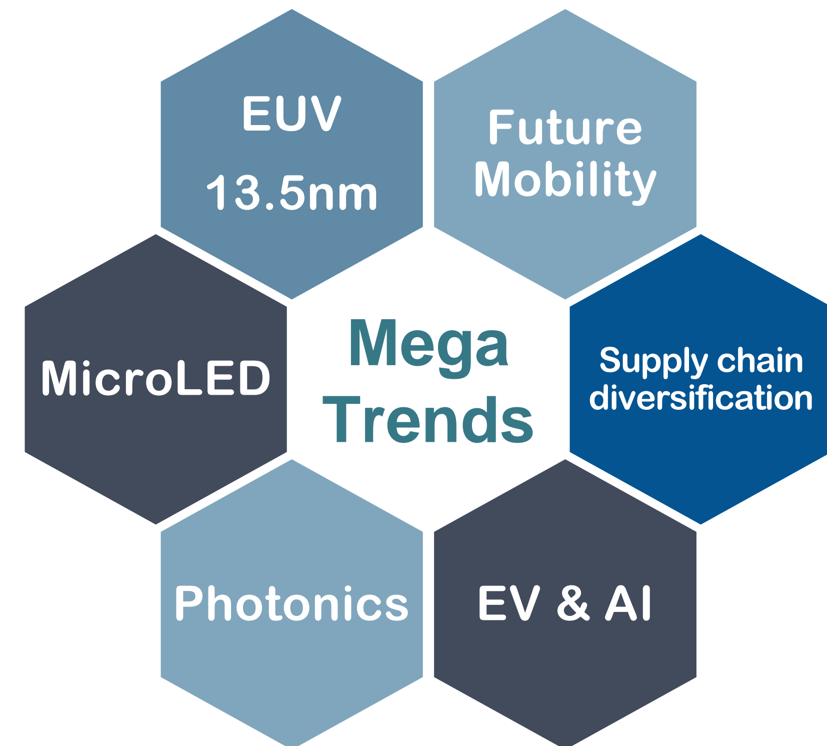
Thomas Gädda, Anton Anisimov, Lily Tseng, Kimmo Karaste, Lauri Manner, Neha Thakur, Uula Kantojärvi, Juha Rantala

We develop materials and processes to address global megatrends



- Next generation materials from strong multi-patent and award-winning R&D team
- One of 2 European suppliers of EUV / DUV Lithography materials.
- Technology platform well positioned for the future with strong pipeline of products

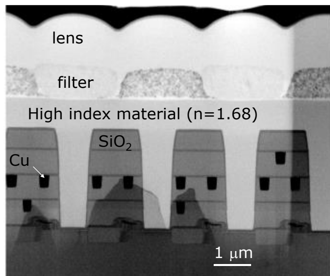
- Global supplier of **leading-edge materials** for the semi-conductor & microelectronics industries
- Global **leader of advanced spin-on dielectrics**. Adopted in sub 3nm semiconductor devices
- Supplier of lithographic **materials used in 5nm & 3nm** semiconductor logic devices
- Audited and certified 'Quality First' production

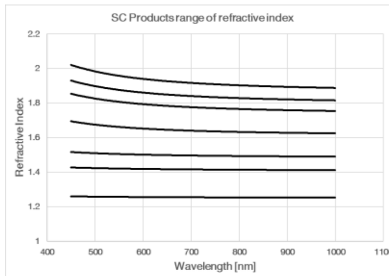


Material Technology Platforms

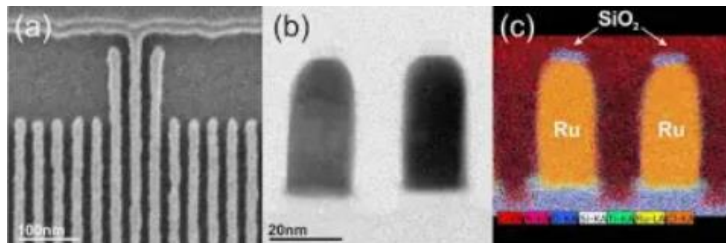
DIELECTRICS

- Traditional spin-on dielectrics
- Optical dielectric, industry leading range of refractive indexes



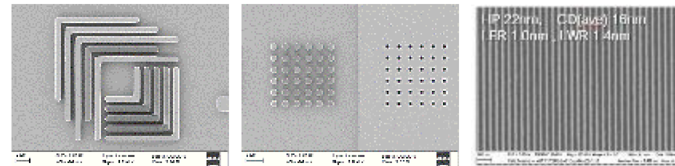


- Novel low k dielectrics for sub 2nm semiconductor devices



PATTERNING MATERIALS

- Inorganic photoresist materials
  i-line – KrF – ArF – EUV – e-beam – NIL

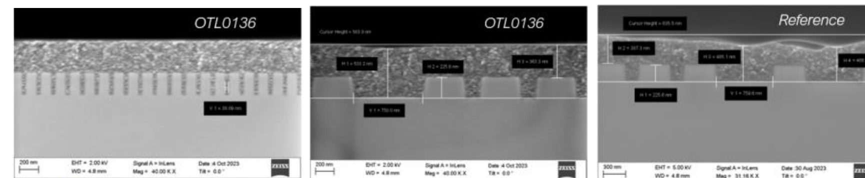


- Silicon hardmask middle layer - SiBARC

Structure	C & E Dense Space
Trench TOP CD	Pass
Trench BTM CD	Pass
Trench Depth	Pass
Trench Profile	Pass

Structure	C & E Via Chain
DD Height	Pass
Via BTM CD	Pass
Via Corner	Pass

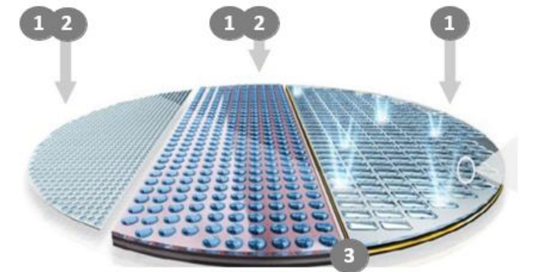
- Organic underlayers – SOC and BARC



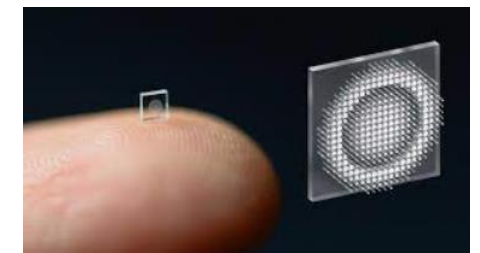
- Auxiliary materials and removers

OPTICAL SILICON RESINS

- High quality, high refractive index silicone adhesives for e.g. MicroLED
- Wafer level optics



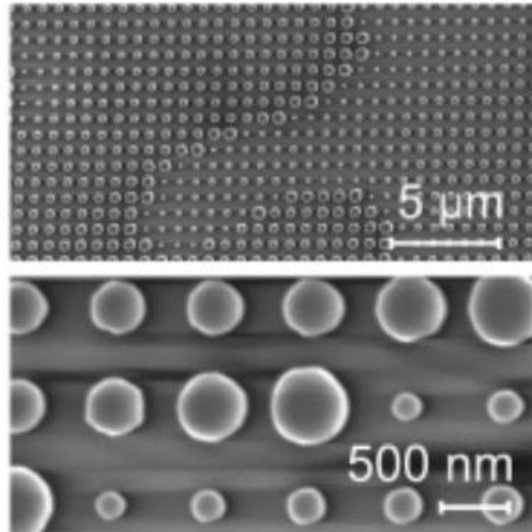
- Metaoptics and NIL processes

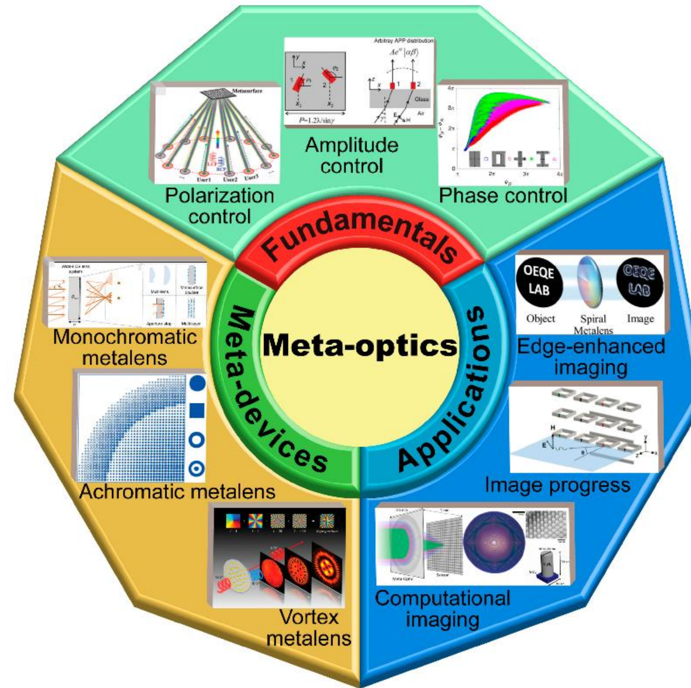


PiBond

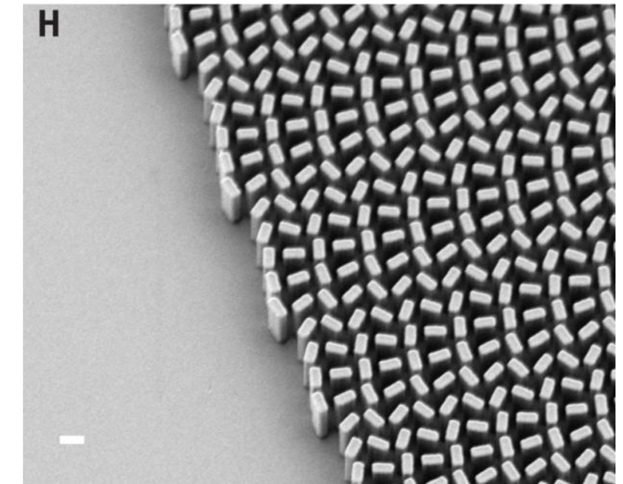
Examples of meta-optical structures and applications

SiO_2





TiO_2



λ_d = 660 nm: W = 85, L = 410, H= 600 nm
λ_d = 532 nm: W = 95, L = 250, H= 600 nm
λ_d = 405 nm: W = 40, L = 150, H = 600 nm

Wang, L., Kruk, S., Tang, H., Li, T., Kravchenko, I., Neshev, D. N., Kivshar, Y. S. Optica 2016, 3,1504

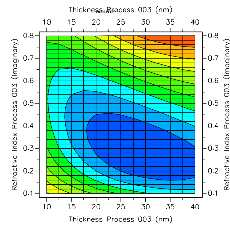
Ou, K., Wan, H., Wang, G., Zhu, J., Dong, S., He, T., Yang, H., Wei, Z., Wang, Z., Cheng, X., Nanomaterials 2023, 13, 1235

Khorasaninejad, M.,Chen, W. T., Devlin, R. C., Oh, J., Zhu, A. Y., Capasso, F. Science 2016, 352, 1190

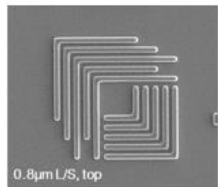
Challenge: produce structures with needed aspect ratio and Δn

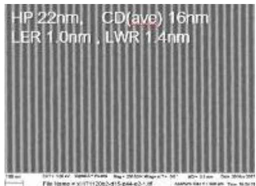
Broad outline of the materials and processes for optical and nanoimprint lithography

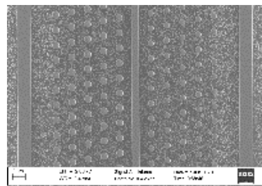
1. Stack and substrate modelling



2 & 3. High Si-% resists

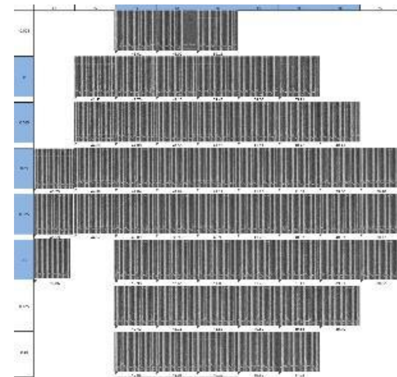


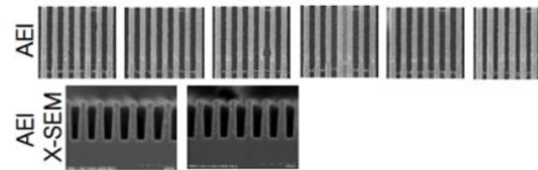


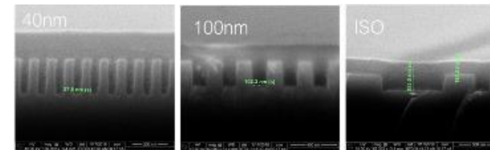


4. Extensive SiBARC, SiHM library

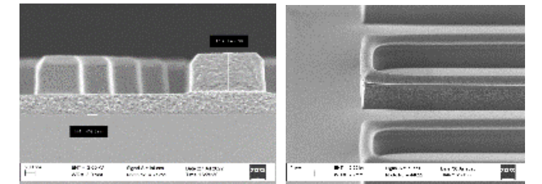
5. Spin-on Carbon (SOC) under layer Planarizing organic coatings



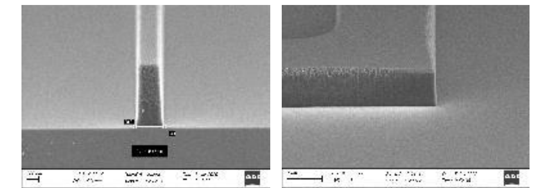


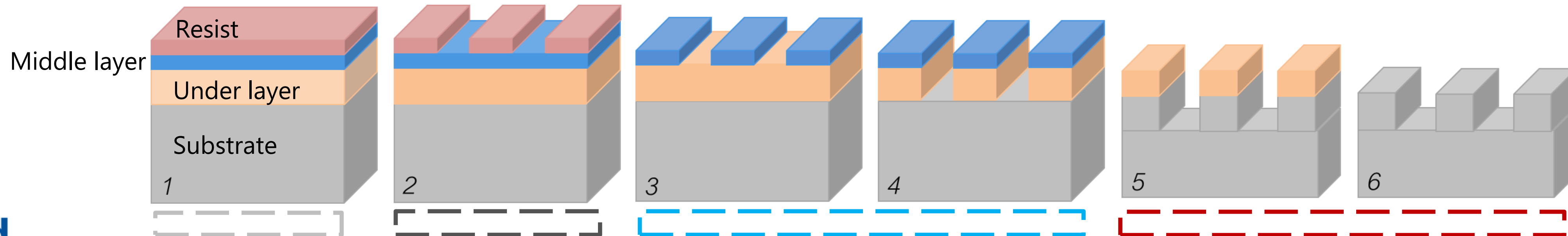


4 & 5. Etch process development

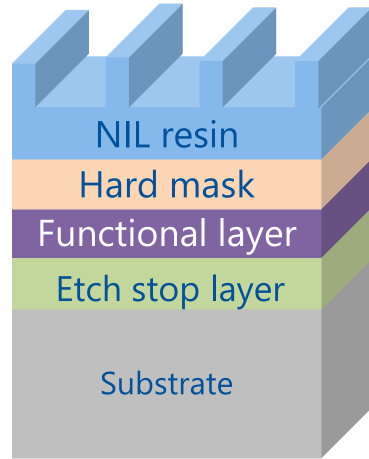


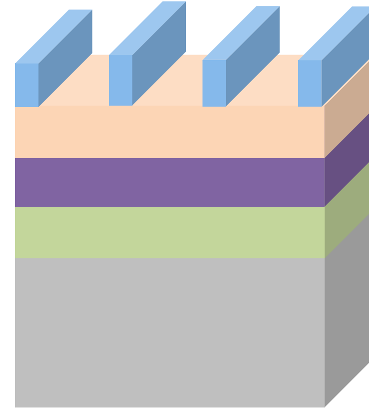
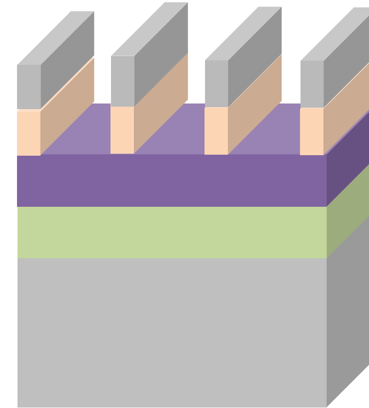
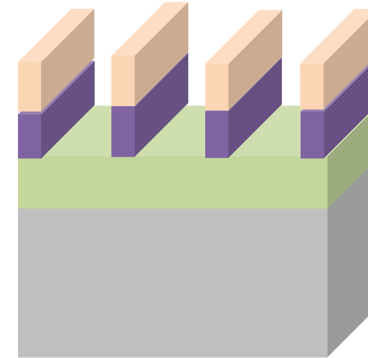
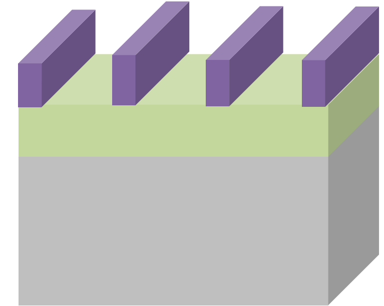
6. Strip solutions and removers





Complete solutions for imprinting and pattern transfer



NIL | Residual NIL resin removal | Hard mask etch | Functional layer etch | OTL residue removal

PiBond Products

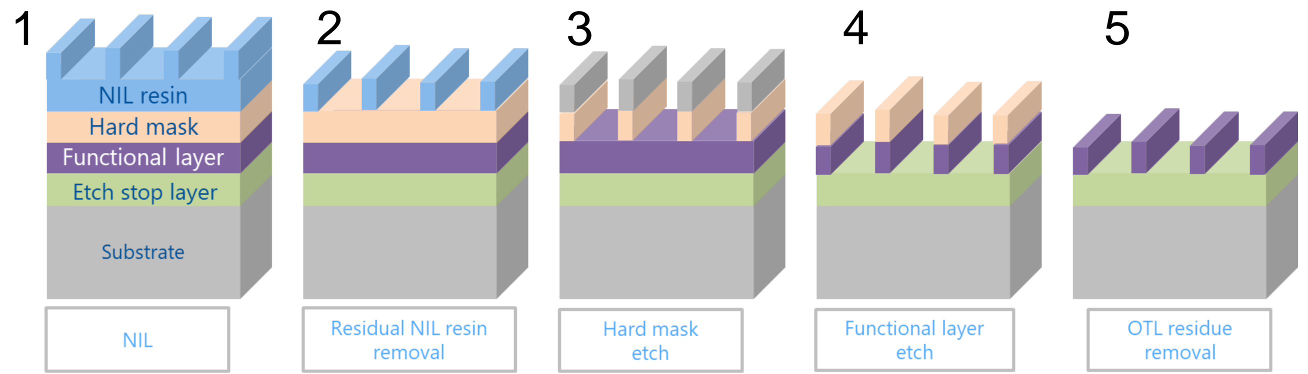
Resist: PRE 500

Hard masks: OTL 500, SH 100

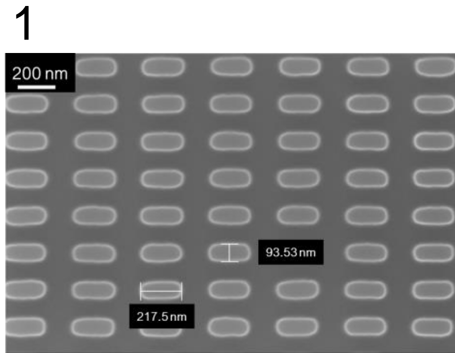
Stripper-remover: PS 300

CASE

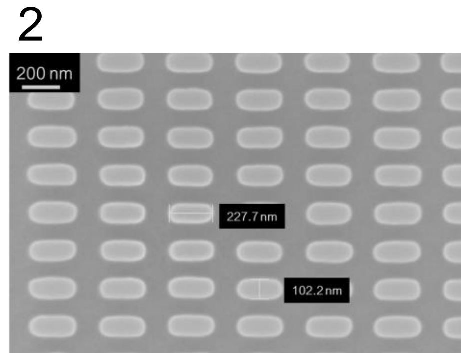
High refractive index patterns



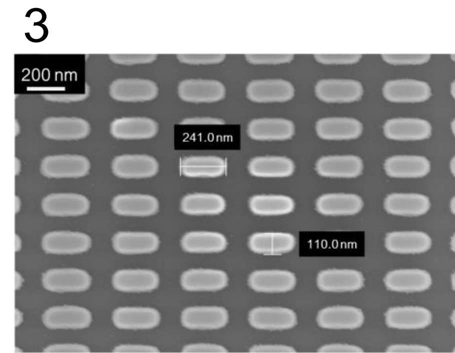
1



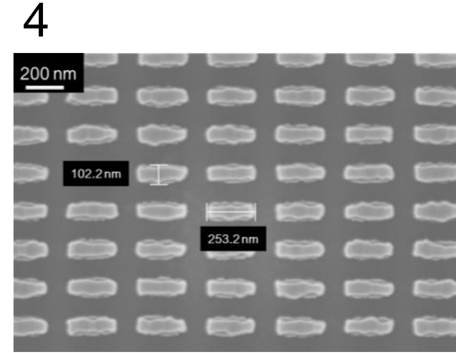
2



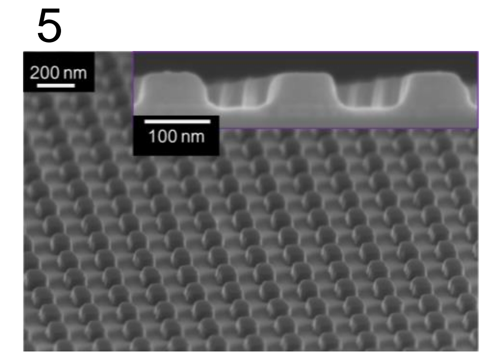
3

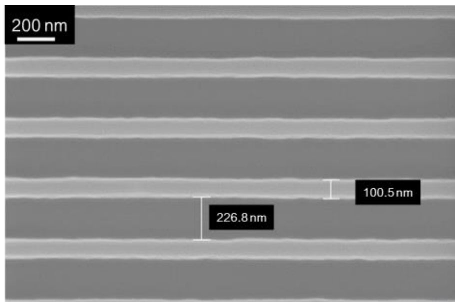


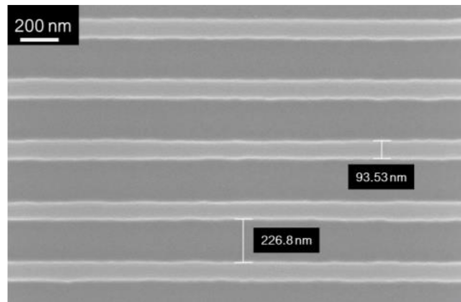
4

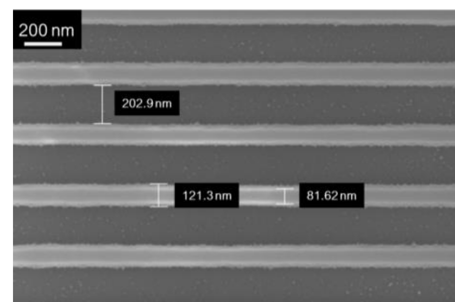


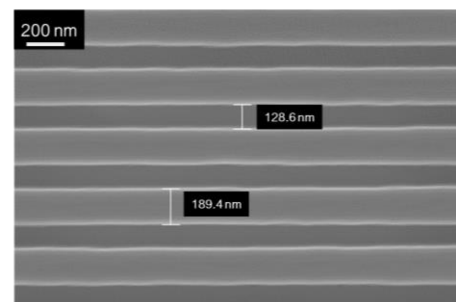
5

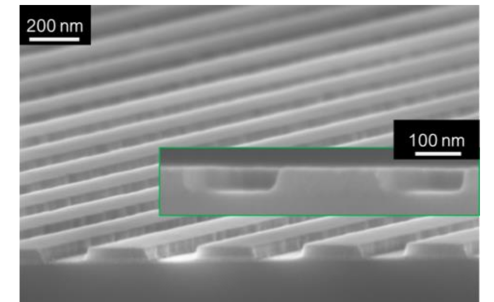












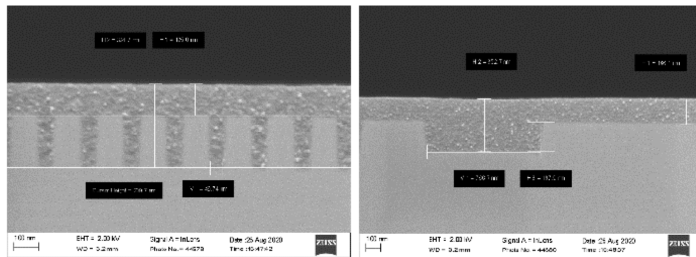
Lithography underlayer materials – organic and silicon hard mask materials

SOC – SPIN-ON CARBON

PRODUCT: OTL 500

- Highest etch resistance in fluorine etch chemistries
- Improved removal rates using liquid removers
- Permits thick coatings for deep etch processes

OTL 500	Property
Carbon content	82%
Ohnishi parameter	2.1
Modulus / Hardness	11.3 / 0.5 GPa
Trace metals	<30ppb



SiHM – SILICON HARD MASK

PRODUCT: SH 100

- SiO_2-like material – spin-coat + bake alternative to CVD
- High inorganic content – permits easy pattern transfer
- Hard mask alternative to chlorine etch chemistries

OTL 500	Property
Silicon content	45%
Oxygen etch rate	<20 nm/min
Water contact angle	65°
Trace metals	<30ppb

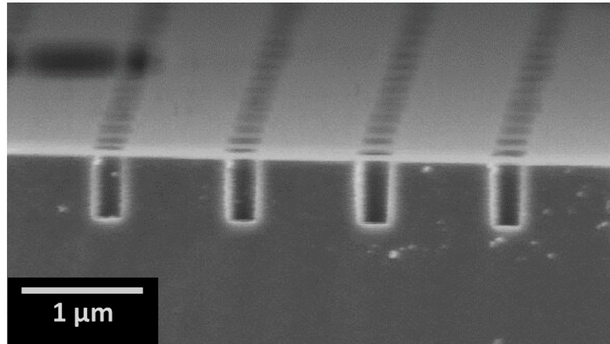
Broad range of substrates and etch processes screened

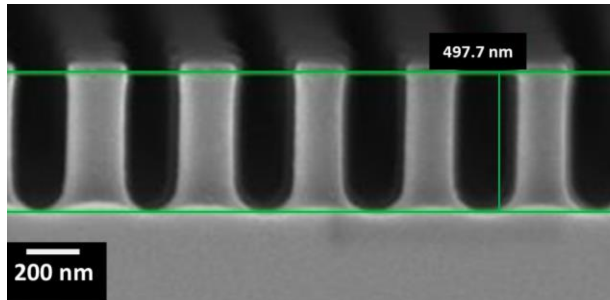
Material	Etch selectivity	Etching chemistry	Etching process
OTL520: NIL resin	1:6	F-based	ICP
OTL520: SH100	1:18	F-based	ICP
OTL520: c-Si	1:15	F-based	ICP cryo
OTL520: a-Si	1:24	F-based	ICP cryo
OTL520: SiN_x	1:2.5	F-based	ICP cryo
OTL520: TiO_2	1:10	F-based	ICP
OTL520: GaN	1:1.5	Cl-based	ICP

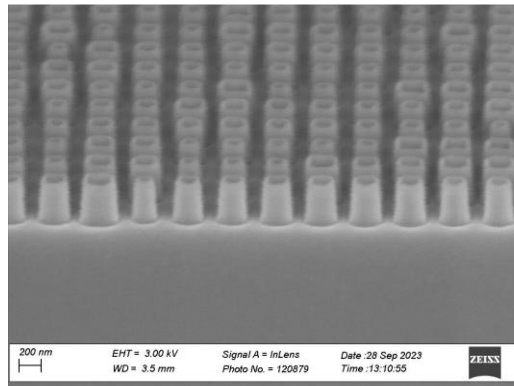
Etch gas chemistries examples: F-based: SF_6 CF_4 CHF_3 C_4F_8 and as mixtures and diluted with Ar
Cl-based: Cl_2 BCl_3 and as mixtures and diluted with Ar
Oxygen: O_2, diluted with Ar

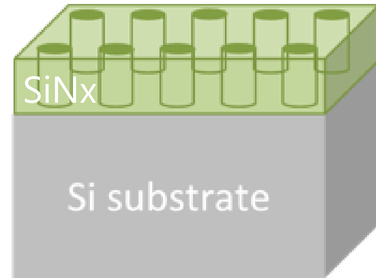
CASE

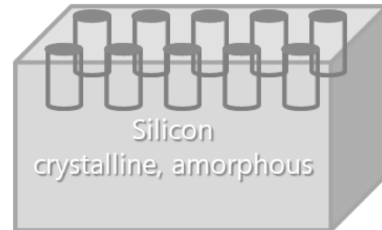
Other substrate materials, gap filling materials for meta structures



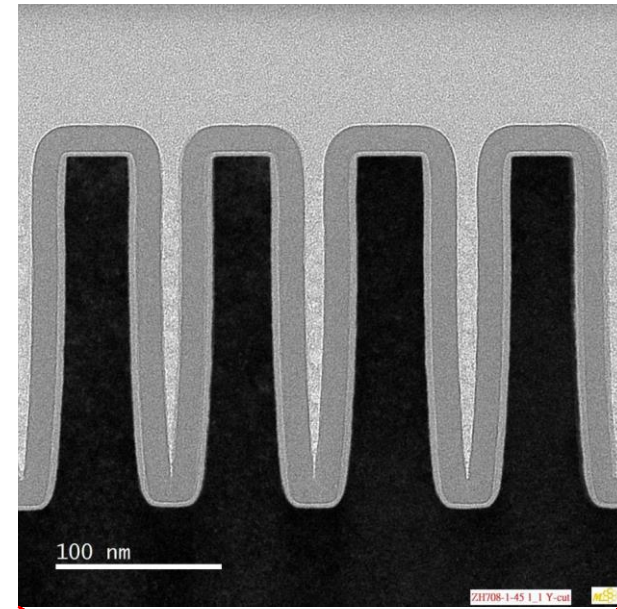


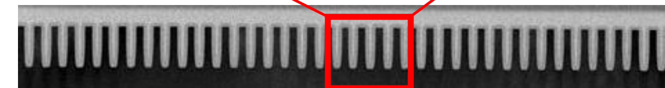






Gallium nitride



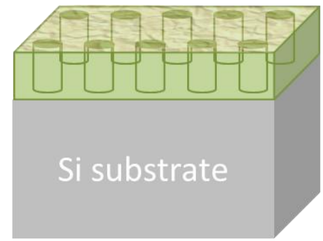


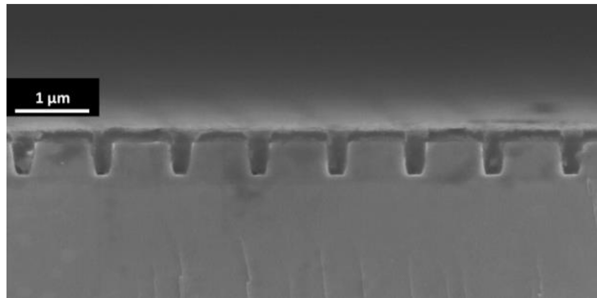
Low refractive index gap fill materials

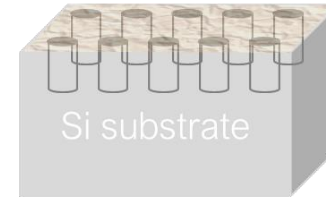
PiBond

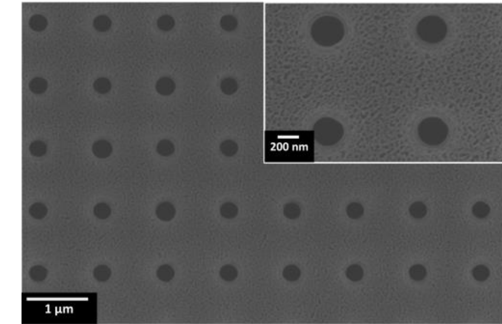
Si and SiN_x development done in collaboration with EVG

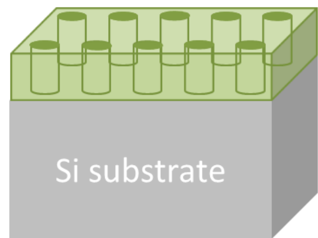
Strip-solutions compatible with substrate materials and etch processes

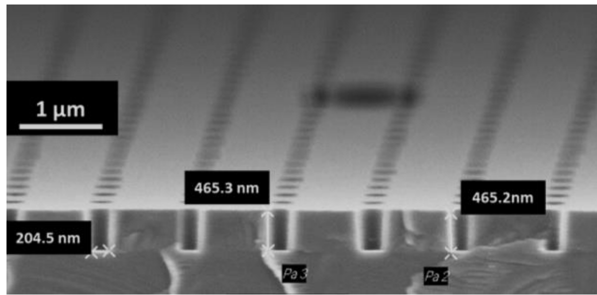


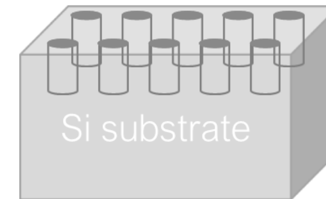












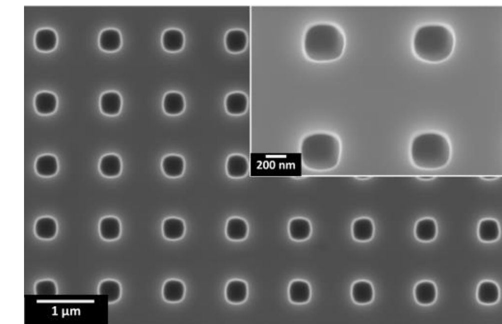


Table. Examples of determined post process removal rates

Material	Etch conditions	Strip Temperature [°C]	Removal rate [nm/min]
NIL resin	SF_6 : Ar	50	90
NIL resin	No etch	50	60
OTL 500	No etch	60	70

Si and SiN_x work done in collaboration with EVG

Thank you!

Let’s enable photonic metastructures of tomorrow!

PiBond materials with engineered precision make advancements in global semiconductor manufacturing!

BUSINESS FINLAND

Grant 1305/31/2022

European Innovation Council

Co-funded by the European Union

Project 190163952