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NAGASE Group

ENHANCING AR WAVEGUIDE PERFORMANCE: THE ROLE OF PROCESS OPTIMIZATION AND MATERIAL SCIENCE

AR/VR/MR - FROM DESIGN TO SYSTEM INTEGRATION AND MASS PRODUCTION, MAY 11-12, 2023

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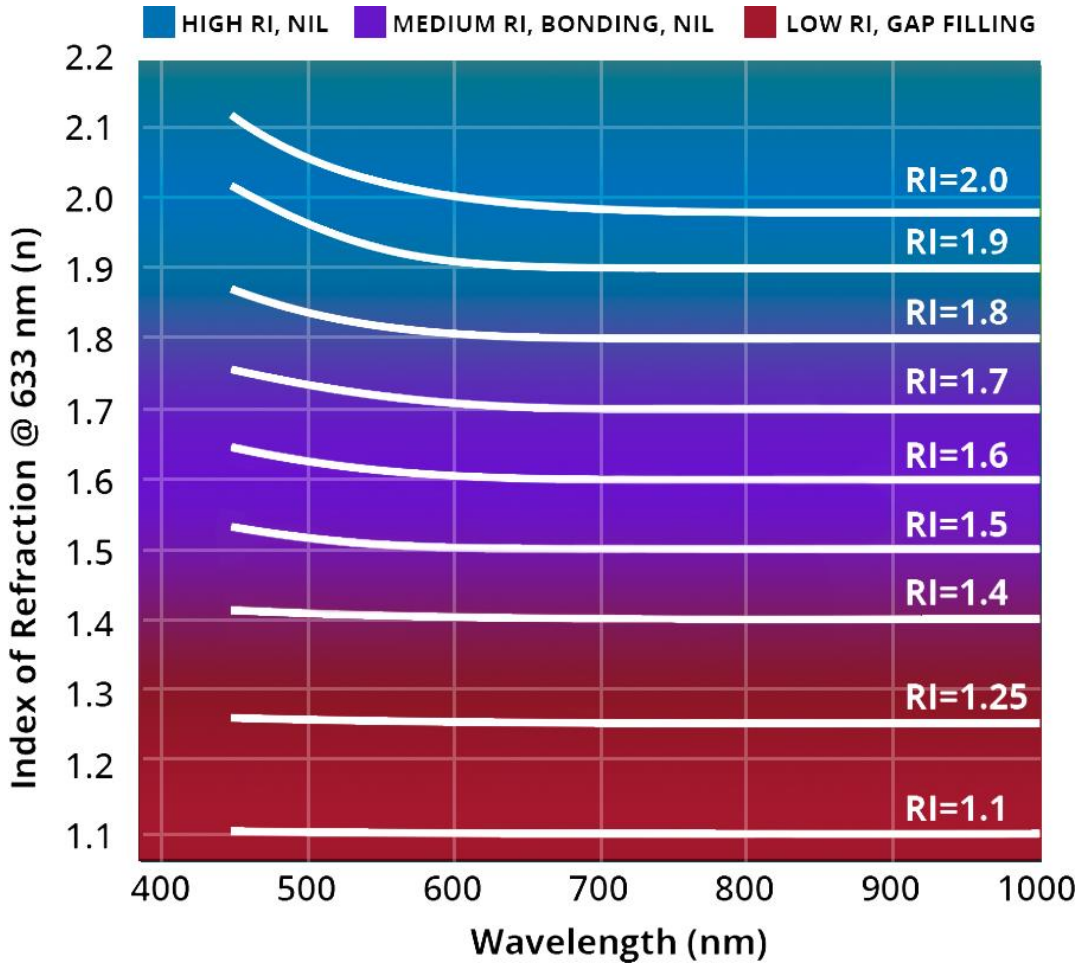
PROCESS OPTIMIZATION AND MATERIAL SCIENCE

- The efficiency of AR waveguides has a significant impact on the performance of the AR system - particularly in terms of image quality, brightness, and battery life.

- Besides the optical design itself, the combined process optimization and material development (with the feedback loop) can help to achieve the targets.
  - Example 1): Minimizing Residual Layer Thickness (RLT) by process and material modifications and optimization
  - Example 2): Stray light control by material development
  - Example 3): Continuous material development

OPTICAL MATERIALS PRODUCTS RANGE



n = 1.5 - 2.0
NIL resins, Optical coatings
& light absorbing coatings

n = 1.4 - 1.6
Optical Bonding and Gap Fill

n = 1.1 - 1.6
Optical Coatings

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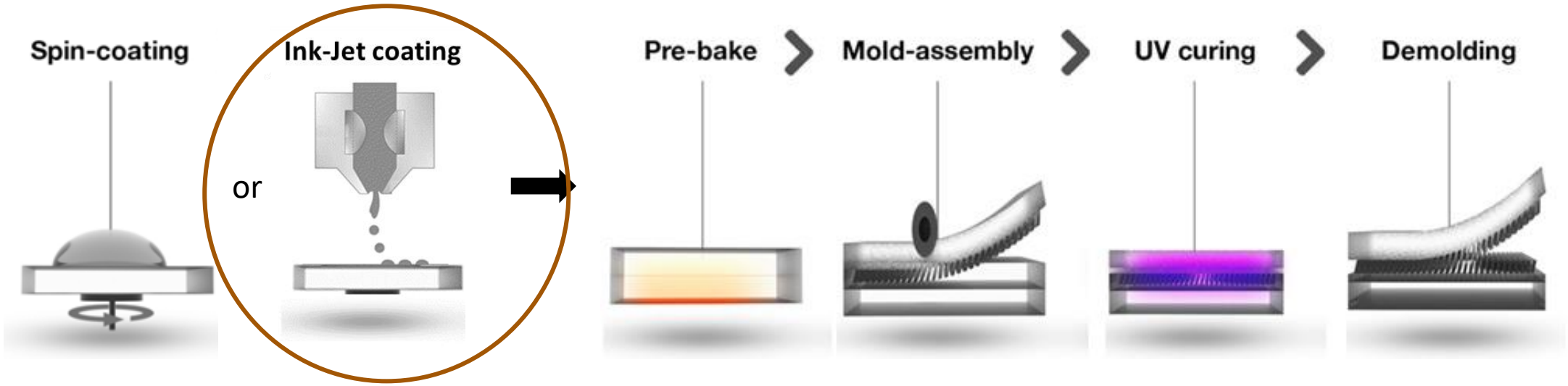
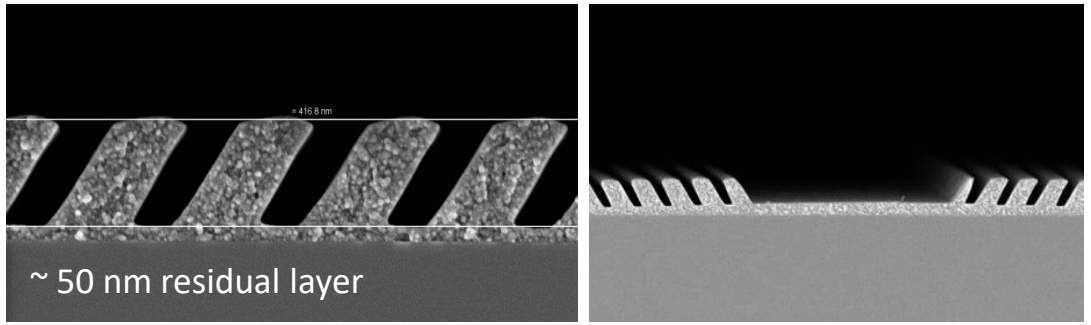
EFFICIENCY IMPROVEMENTS BY PROCESS OPTIMIZATION

NIL PROCESS USING INK JETTING



- **High RI Optical NIL resins**
  - Refractive index from 1.55 to 1.92
  - Spincoatable (IOC) and ink-jettable (IOP) resins
  - Low haze and light scattering
  - High transparency
  - Thermally stable
  - Low RLT

IOC-133 (n = 1.9)



Slanted grating master manufactured and provided by NIL Technology AsP.

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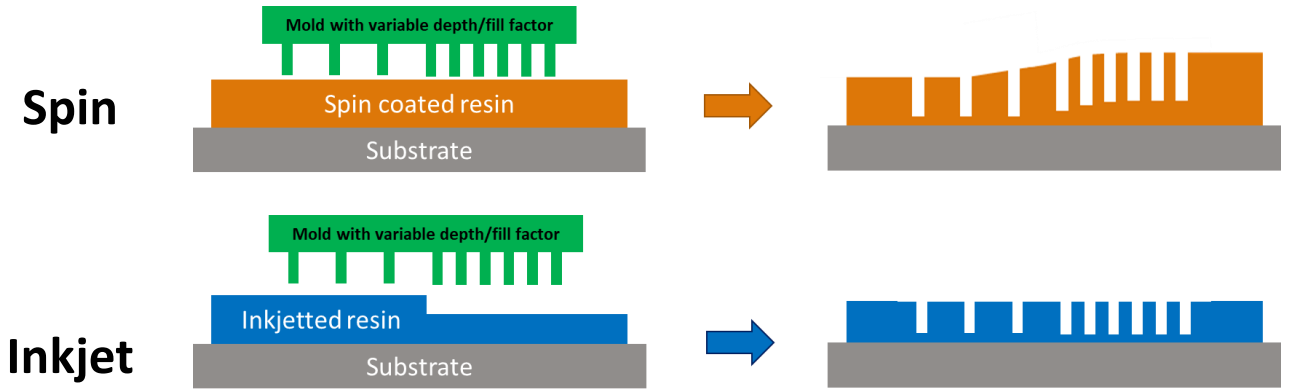
POTENTIAL BENEFITS OF INK JET+ NIL APPROACH

Inkjetting allows	Benefit	Note
Use the coating only there where it is needed	Material savings, Optical efficiency improvement	Might require changes for the optical design (edge effects etc.)
Freely selectable shape of coated area (on the same wafer)	Material savings, More units per wafer ? Panel size substrate	Design freedom
Variable coating layer thicknesses on the same wafer	Optimized local thickness for targeted RLT, RLT layer minimized	Improved Device Efficiency
Use of different inks on the same wafer	Different product variants on the same wafer	Design Freedom, New designs requiring multiple inks

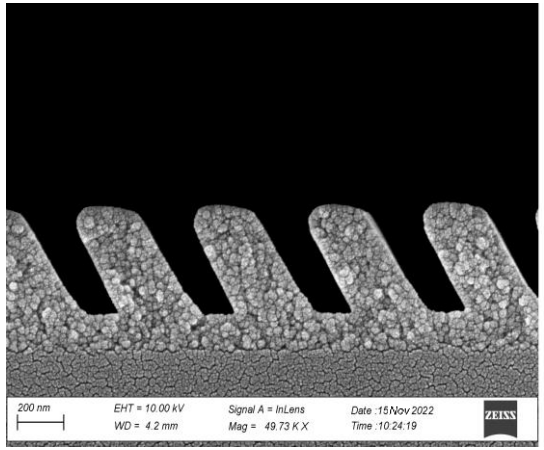


Uneven RLT
(Residual Layer Thickness)

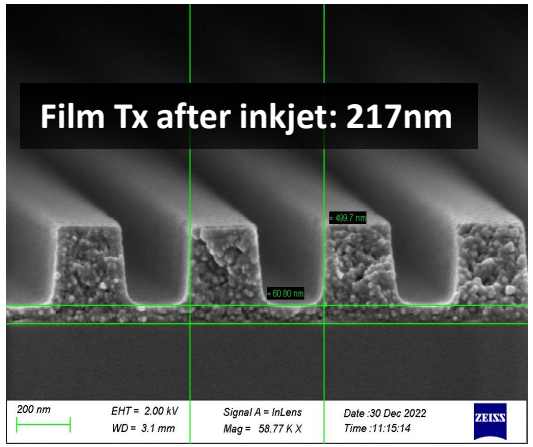
Uniform RLT

NIL PROCESSABILITY - RLT OPTIMIZATION

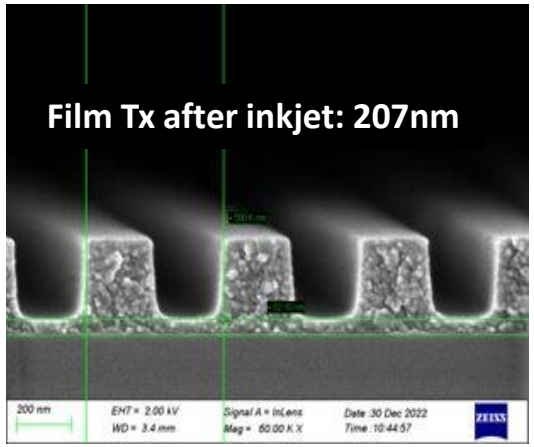
IPO-912:
Slanted gratings



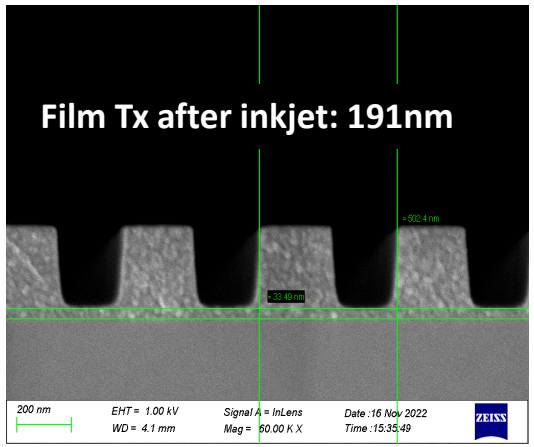
IPO-912:
500nm period binary gratings with 255nm heights



RLT: ~57 nm



RLT: ~48 nm



RLT: ~29 nm

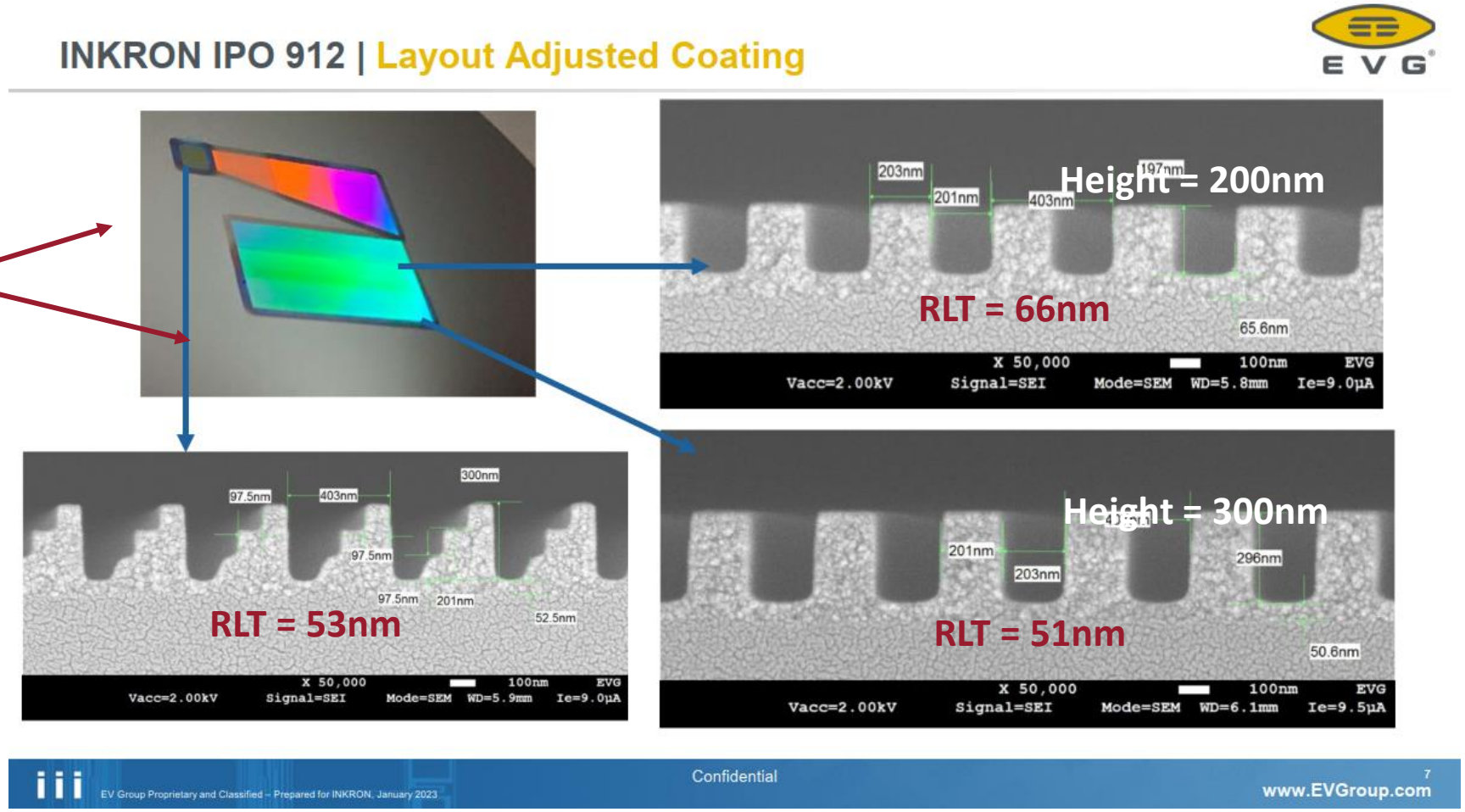
Inkjet conditions:
Printer: Suss PiXDRO LP50
Printhead: DMC Samba
Substrate Temp: 25°C
Ink Temp: 27°C
Drop size: 4 pL (1dpd, 27-29V, 2.5µs)

- Optimized layer thickness allows RLT optimization
- RLT's as low as 30 nm can be achieved (with 1.9 RI NIL material)

RLT OPTIMIZATION OF A WAVEGUIDE

Optimized inkjet volumes for waveguide height modulations and grating profiles

Uniform RLT for the whole design

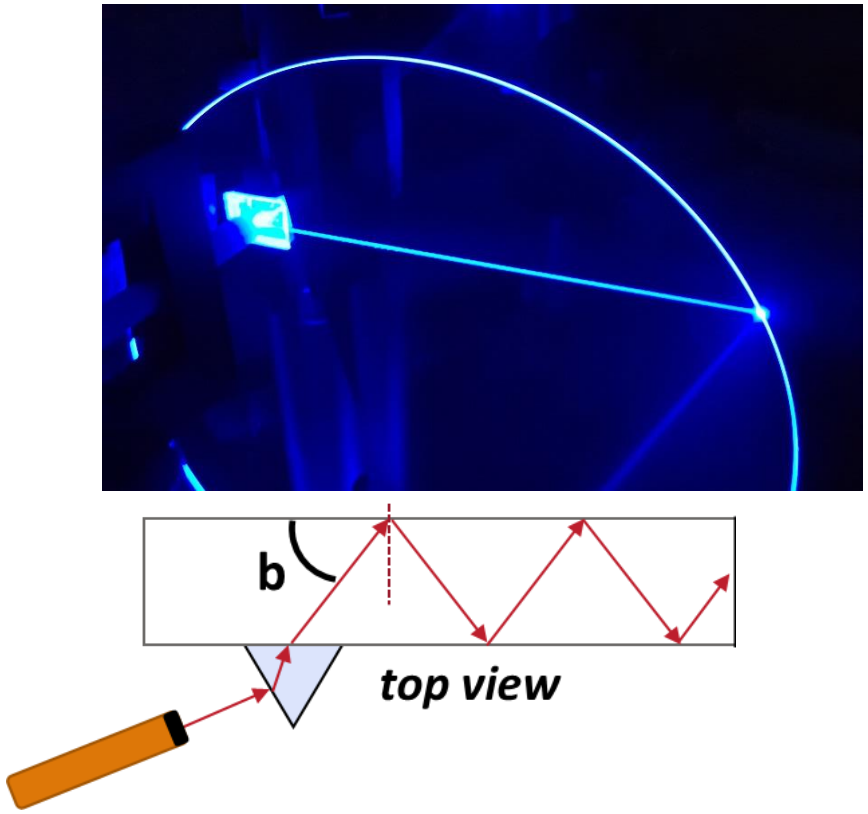


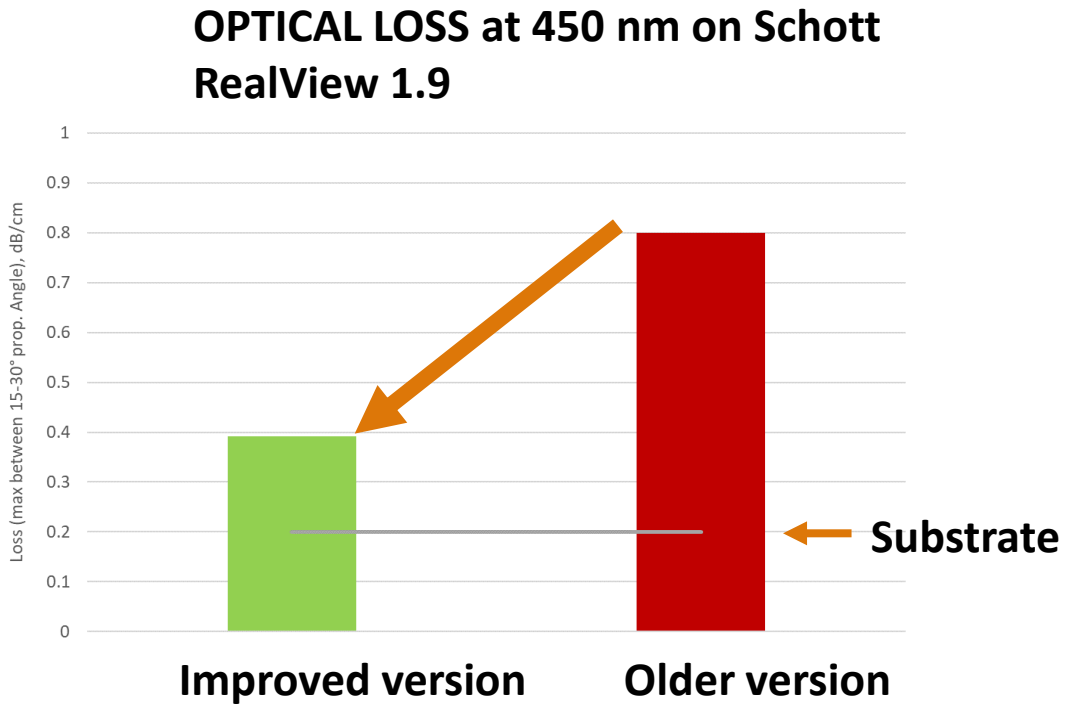
This project has received funding from the European Union's Horizon 2020 research and innovation program under the Grant Agreement n°958472, project TINKER.

MATERIAL OPTIMIZATION, PROCESS STABILITY AND OPTICAL LOSSES

IMPROVED OPTICAL PROPERTIES

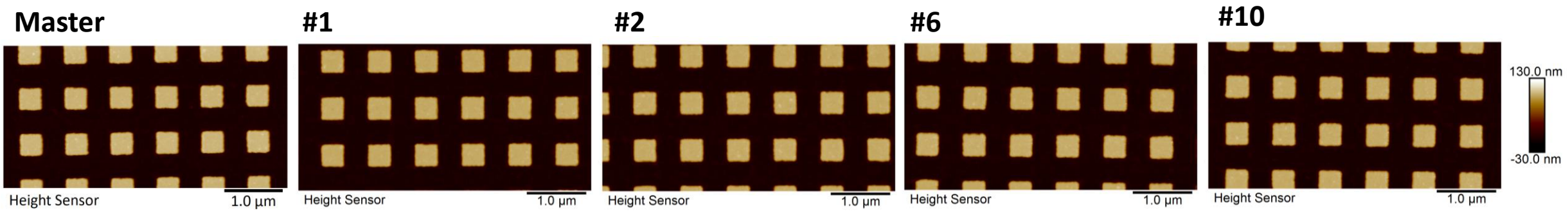
- Constant development of the nanofiller and resin system
- Significantly improved optical properties <u>while maintaining the good processablity</u>



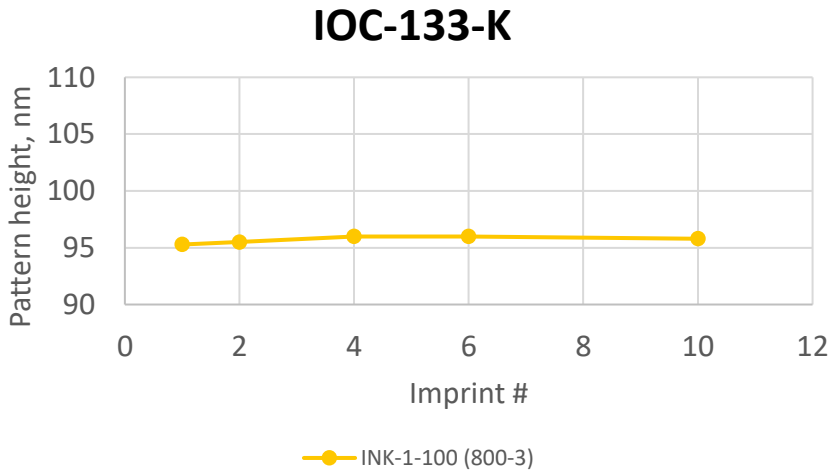


CONTINUOUS DEVELOPMENT - IMPROVED DIMENSIONAL STABILITY – IOC-133-K

- Improved dimensional stability at low layer thicknesses (<200nm) implemented through formulation changes
- Layer thickness ca. 150 nm



	Structure height, nm						Difference, nm
Structures	**Master**	#1	#2	#4	#6	#10	
Rect. pillars Period: 800nm	98.3	95.5	95.5	96.0	96.0	95.8	**+0.3**



Good pattern fidelity

Negligible pattern height changes

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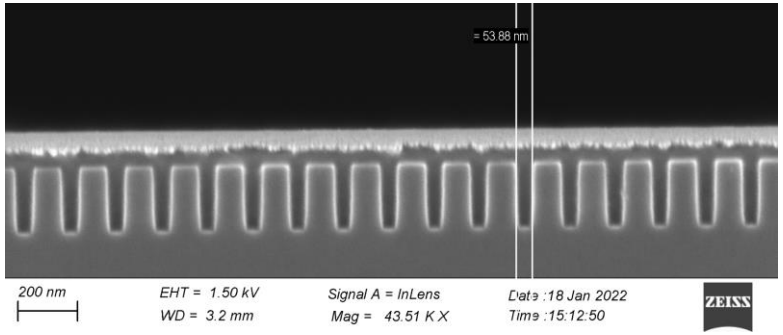
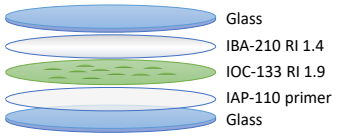
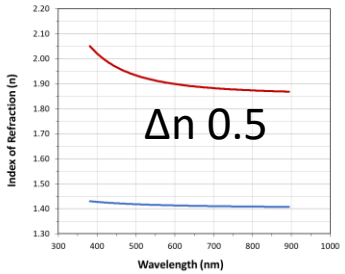
GAP FILLING, OPTICALLY CLEAR ADHESIVES

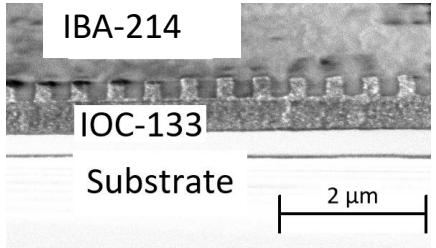
- Protective coatings and stacking
- Delta n between the gratings and the gap fill material
- Basic properties
  - RI 1.4, 1.5 and 1.6, no nano-particles
  - Excellent transparency, no haze or scattering
  - Excellent gap-filling properties (< 10 nm)
  - Spin-coating, possible to formulate for inkjet
  - Thermally stable, can withstand reflow temperatures



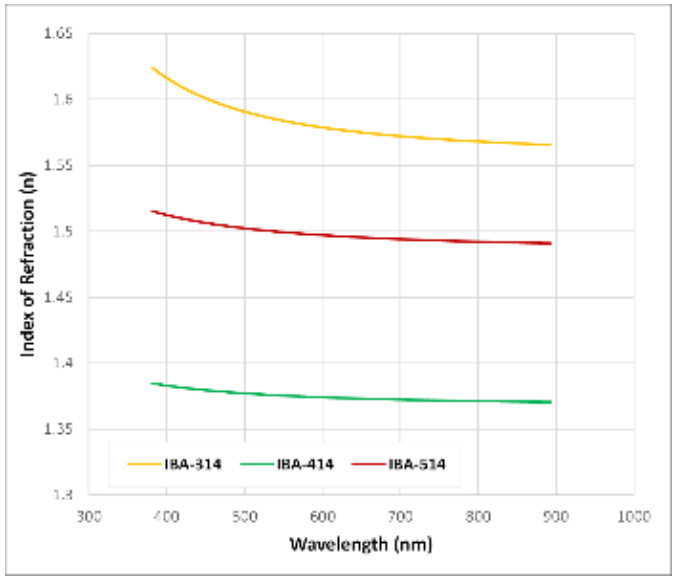
***n* = 1.4** 50nm gap-fill







Sensor structure, 1.9 RI imprinted layer gap filled with 1.4 Ri adhesive layer



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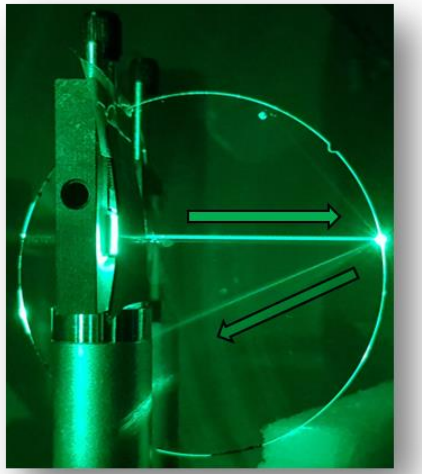
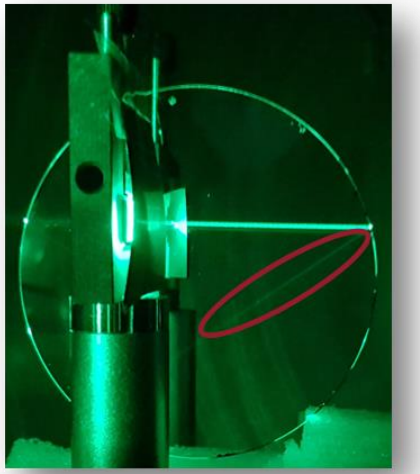
ELIMINATION OF INTERNAL REFLECTIONS

INDEX MATCHING BLACK MATERIAL ELIMINATES EDGE REFLECTIONS



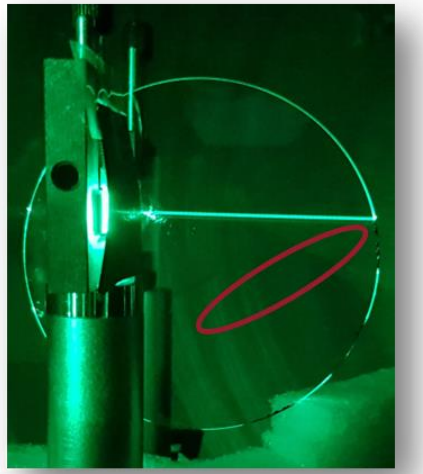
No black edge coating

~10% reflectance



"Standard" 1.5 RI black edge coating

~3% reflectance

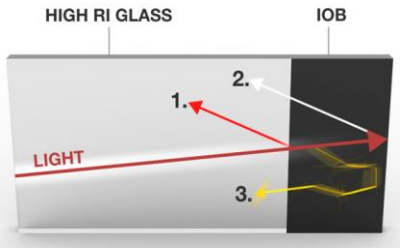


1.9 RI black edge coating

~0% reflectance

SCHOTT
glass made of ideas

**Schott 1.9 RealView glass wafers*



- Index matching of substrate and edge black material eliminates reflections caused by RI difference at the interface
- High Optical Density (OD) absorbs the light entering the blackening layer
- Balanced formulation removes scattering
- Both thermal and UV versions (RI 1.7- 1.9)

- **Benefit:**
- Improved contrast and image quality

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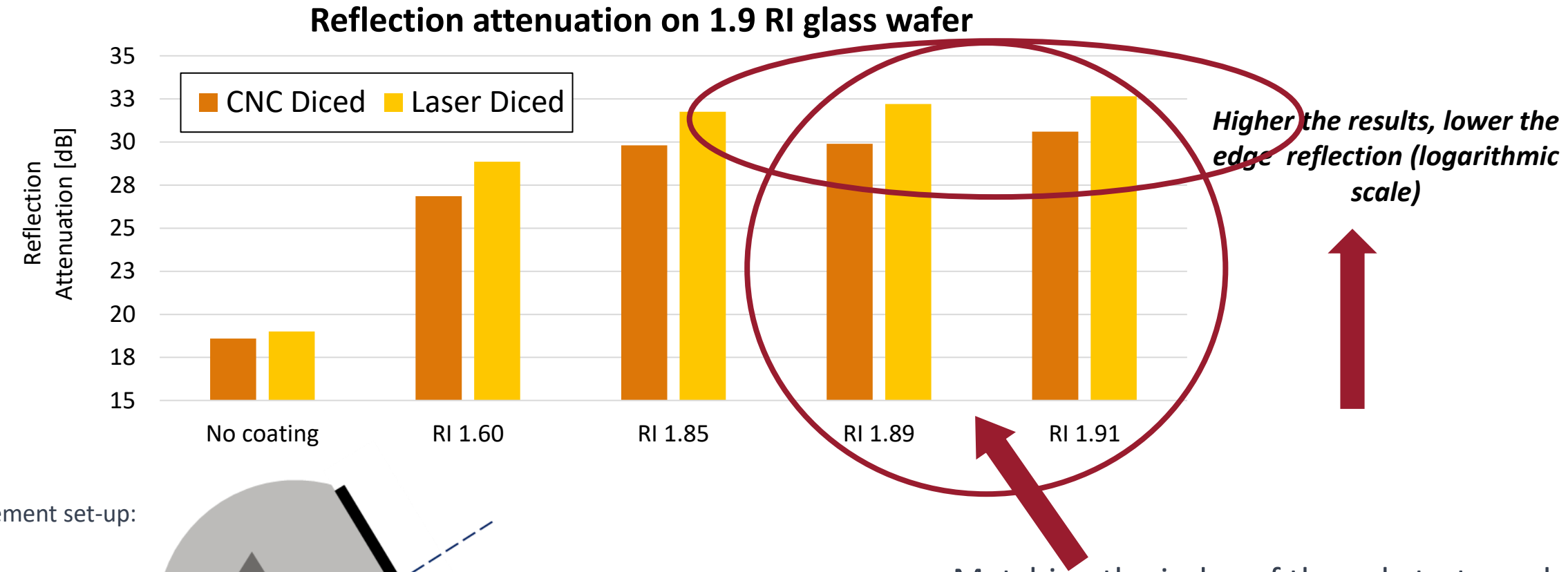
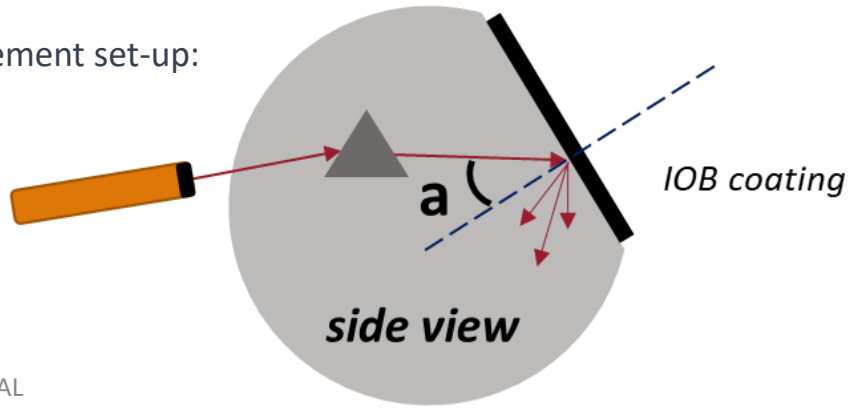
OPTICAL ANALYSIS OF INDEX MATCHING



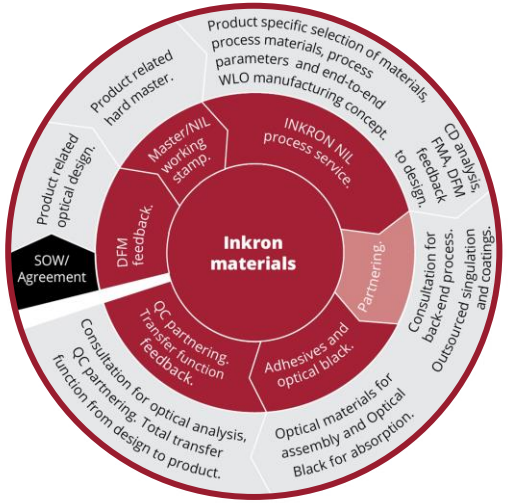
Measurement set-up:

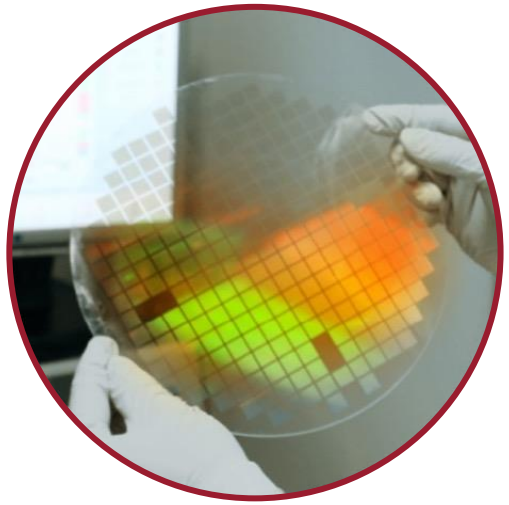


Matching the index of the substrate and the black material at the edge is the most effective method to reduce the internal reflections.

CONCLUSION

- Inkjet + NIL is one of the key approaches for RLT optimization. Inkjet coating will be a major manufacturing method in combination with NIL process.
- Material development, integrated with process know-how and continuous process feedback, is a critical component of AR glass waveguide manufacturing and its progress.





MATERIALS → **PROCESS SERVICE** → **OPTIMIZED SOLUTION**

THANK YOU

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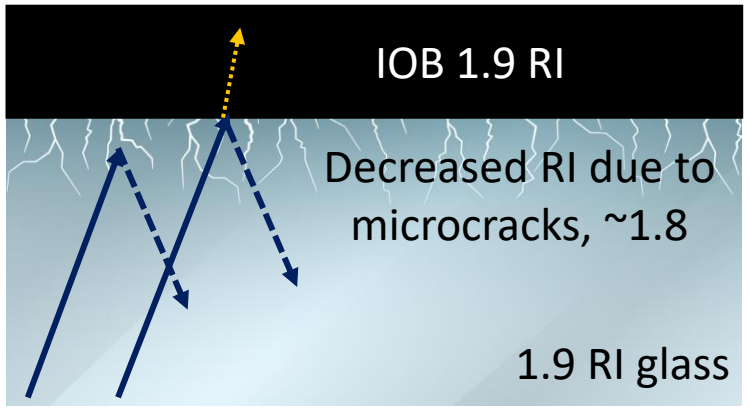
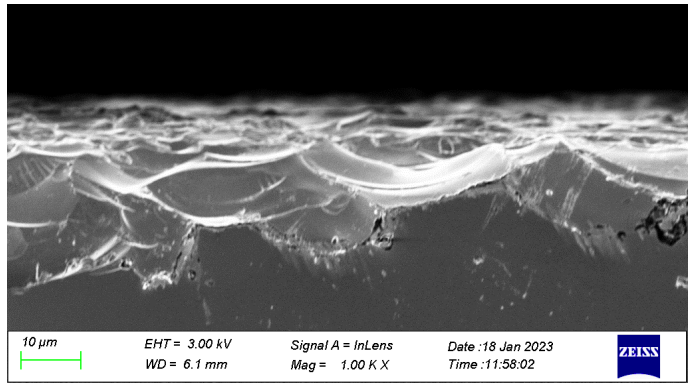
EPIC QUESTIONS

- What can we do for you ?
  - Materials for Wafer Level Optics
  - Material development for WLO
  - Prototyping NIL services
  - Open for joint R&D projects
- What can you do for us ?
  - If you work with diffractive optics, meta lenses, AR glasses etc. we would be keen to hear of you and discuss if there are any joint areas of interest

OPTICAL ANALYSIS OF EDGE QUALITY EFFECTS

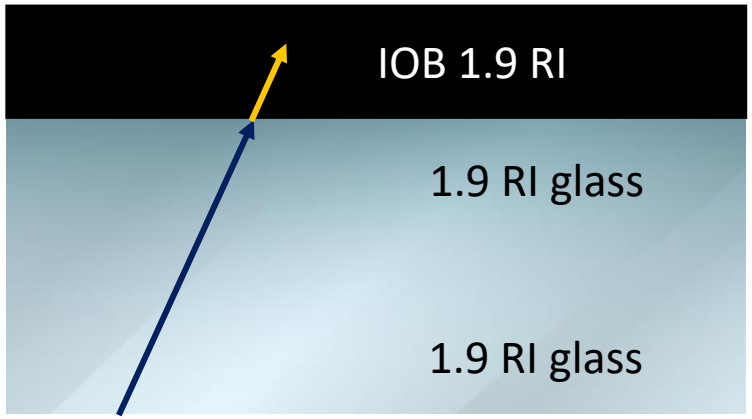
CNC Diced

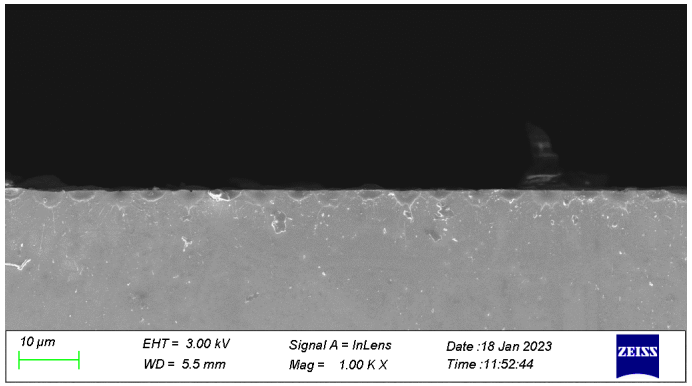




Side SEM

Laser Diced*





**Corning Laser Technologies GmbH Laser nanoperforation, speed 60 m/min, edge roughness Ra = 0.33 µm*