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IMAGING OF LIQUID AND DRY FILM PHOTORESISTS

– BEST PRACTICES FROM AN IMAGING POINT OF VIEW

SCHMOLL MASCHINEN GMBH
DENNIS PUSCH
21.05.2025

PCMI SPRING CONFERENCE 2025

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...one step ahead.

PCMI
Photo Chemical Machining Institute

Imaging of Liquid and Dry Film Photoresists – Best Practices From an Imaging Point of View

Presentation by: Dennis Pusch

Imaging of Liquid and Dry Film Photoresists – Best Practices From an Imaging Point of View

ABSTRACT

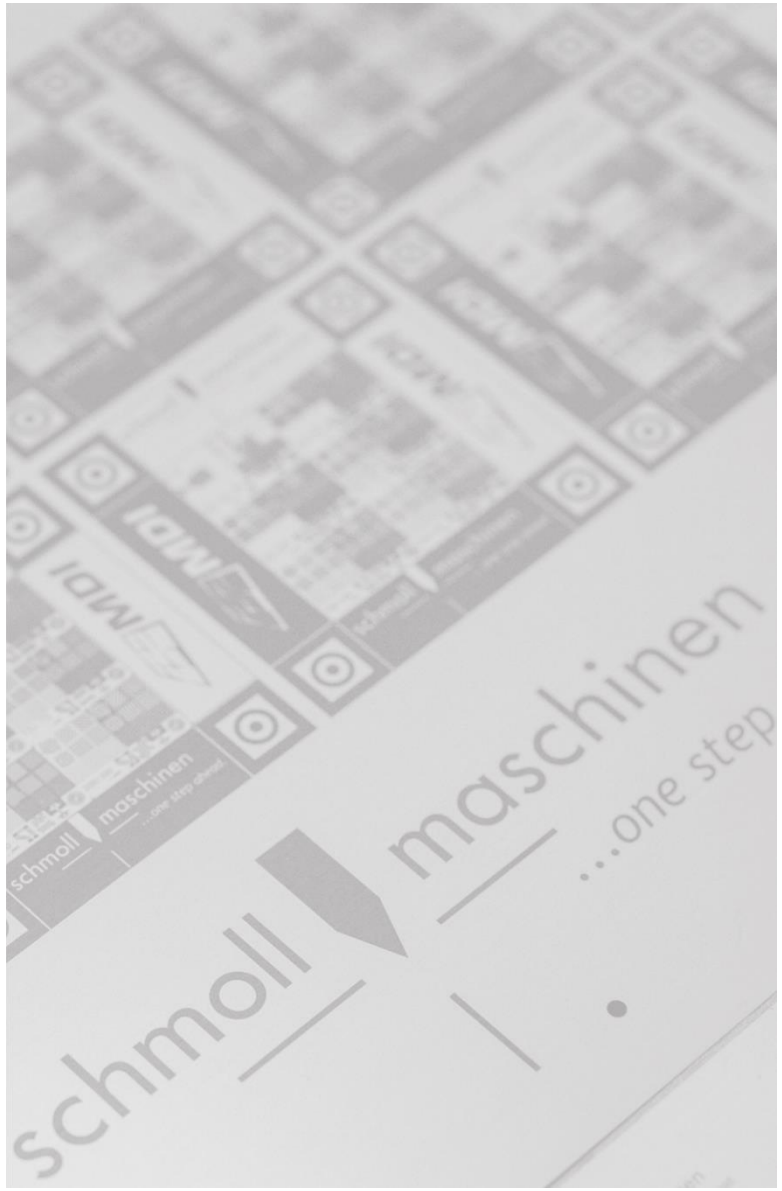
In modern microelectronics and PCM manufacturing, resist materials are critical to the lithography process used to create and form complex patterns on a substrate.

Two of the most common resist types are liquid resist and dry film resist, each offering specific advantages and disadvantages depending on the manufacturing process requirements.

While Liquid resist is a liquid form of photoresist applied to the surface of a substrate by spin coating, this technique enables a thin and uniform coating, making it particularly suitable for high-precision applications.

In contrast, dry-film resist is applied to the substrate in the form of solid films by a heat-depositing lamination process. This process may be mechanically more efficient and offers greater planarity over larger areas, suitable for applications where a uniform film thickness is required.

Since photolithography is considered a crucial technology for creating complex patterns and shapes in the chemical etching or PCM industry, this presentation will focus on a practical evaluation of working with both liquid and dry film resists using modern direct imaging technology.



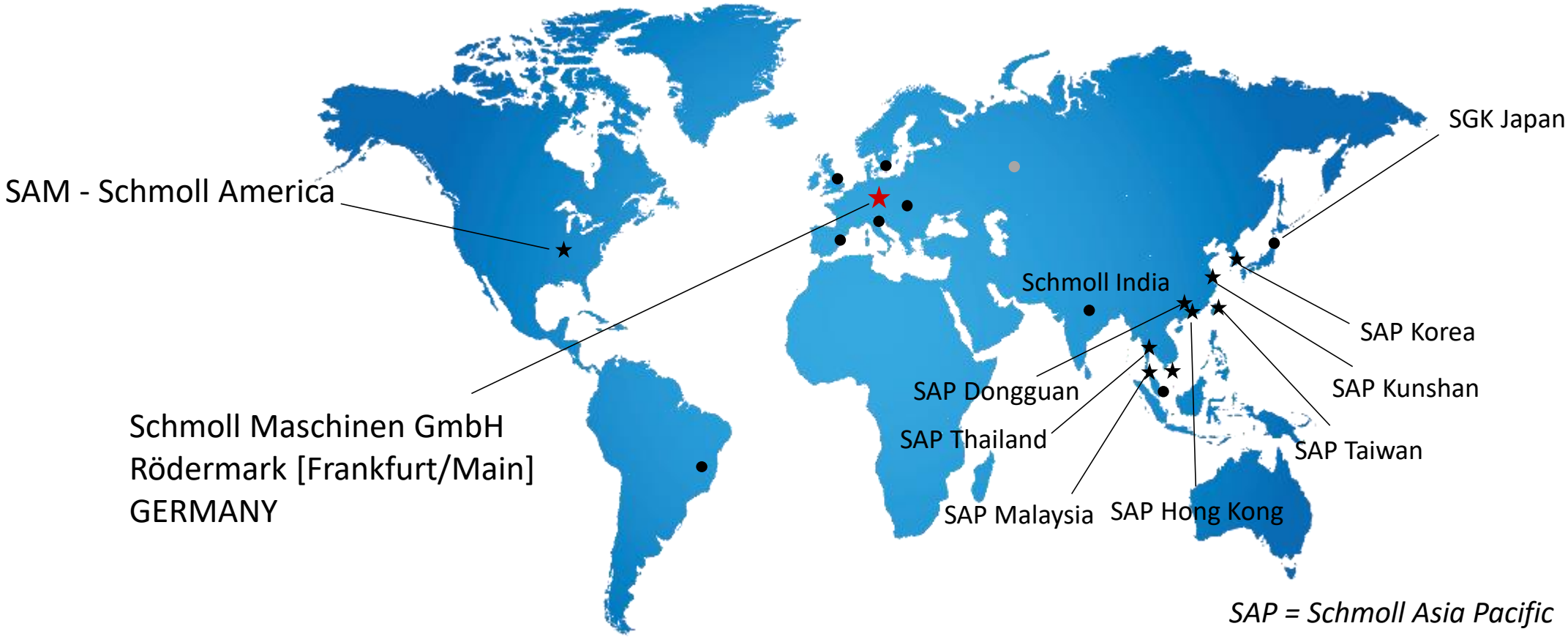
SCHMOLL MASCHINEN GMBH
COMPANY PROFILE

schmoll maschinen OPTRONICS

- Business: Worldwide supplier for PCB/Substrate technology
- Segment: High Quality equipment for Mechanical and Optical PCB processing & related markets & applications
- Location: Rödermark/ Germany [near Frankfurt/Main]
- Employees: Germany over 350, worldwide more than 500
- Capacity: up to 100 Machines/month
- Installation: worldwide 16,500 units
- Founded: 1943 by Heinz Schmoll
- Company profile: Family business (President Mr. Thomas Kunz)
- PCMI Member: Since 2024

Made in Germany

SCHMOLL MASCHINEN GMBH
INTERNATIONAL FOOTPRINT



SAP = Schmoll Asia Pacific

→ Market presence and **customer proximity**

Mechanical Micro Machining

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Machines:
Drilling/Routing
Registration, Punch

Made in Germany

Optical Micro Processing

schmoll optronics

Machines:
Laser Drilling & Cutting
Direct Imaging

Department: MDI

- Own production facility
- Own software department
- Team of technicians & engineers
- Total: **40** people dedicated to the **Direct Imaging** product line

SCHMOLL DIRECT IMAGING
PRODUCT LINE - HIGHLIGHTS

schmoll maschinen OPTRONICS

Automated Line

MDI-TTG & ROBOMATION

- Automatated In-Line system (**<10 Sek.** *)
- Complete system solution DI & Automation from **single source**
- Can be integrated in line or as island solution possible
- [Conveyer to conveyer]
  [loader to unloader]

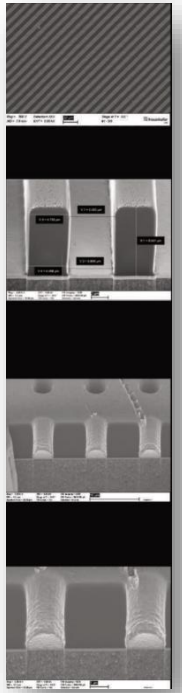
Tandem Table Platform

MDI-TTG (Tandem Table)

- Efficient Tandem-Table-Design, max. Panelformat **24“x36“ (per table)**
- Optional Gantry-Mode for 54“x36“
- **Multi-Wavelengths**-system for all applications

24“ = 610 mm
36“ = 914 mm
54“ = 1371 mm

Fineline Imaging (7µm L/S)



MDI-ST ULTRA

- Highest resolution & accuracy; Ultra-Platform
- Resolutions of **7 µm L/S** (and smaller)
- Installation base and Application-Know-how

Reel-to-Reel

MDI-FLEX

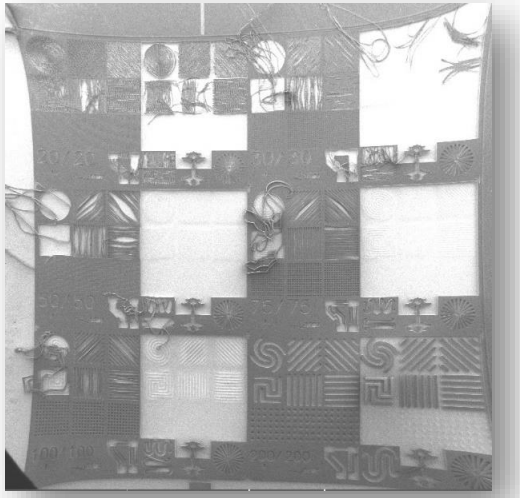
- Reel-to-Reel Platform
- Vacuum solution for Flex-materials
- Autom. Winder & Unwinder

*Throughput based on panel format 24“ x 18“ at exposure energy of 25 mJ/cm², standard 2-4 Target-Registration, LLS30 Photohead resolution

PCM
SUMMARY TABLE OF KEY CHALLENGES IN PCM

Most critical challenges that PCM manufacturers face affect precision, yield, environmental compliance, and cost-efficiency.

Challenge	Impact	Common Causes
Etch Uniformity	*Inconsistent product quality*	*Poor bath control, resist variation*
Etchant Management	*Poor process control, waste*	*Degraded chemicals, oxidation loss*
Undercutting	*Dimensional inaccuracy*	*Isotropic etching, long etch times*
Environmental Compliance	*Legal/financial risk*	*Hazardous chemical disposal*
Cost and Throughput	*Higher operational costs*	*Low yields, inefficient processes*
Resolution Limits	*Feature size limitations*	*Mask quality, resist resolution*
Photoresist Issues	*Pattern defects, rework*	*Poor adhesion, contamination*
Process Scaling	*Inconsistent results in mass production*	*Equipment limits, parameter shifts*



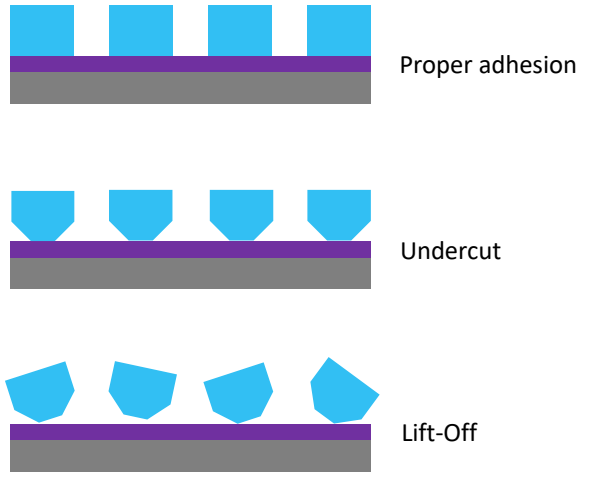
Picture: SEM Image – Fine feature design, adhesion loss

Process Control and Uniformity

- **Challenge:** Achieving consistent etch depth and pattern accuracy across the entire surface.
- **Why it matters:** Uneven etching can cause dimensional errors, poor resolution and consequently product failure
- **Possible causes:**
  - **Variations in photoresist coating or exposure**
  - Uneven agitation or temperature in etching bath
  - Inconsistent chemical concentration or flow rate

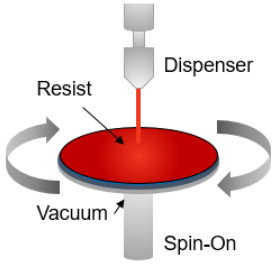
Photoresist Adhesion and Integrity

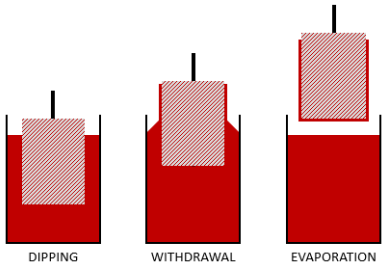
- **Challenge:** Poor adhesion or defects in the photoresist can lead to pinholes, lift-off, or pattern loss during etching.
- **Possible solutions:**
  - Improved surface preparation and cleaning
  - **Optimized** soft bake and **exposure parameters**

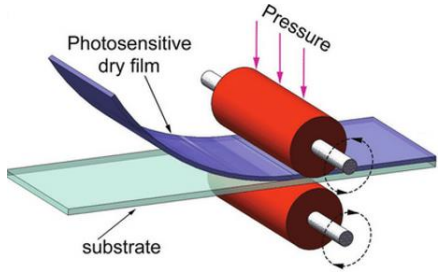


Content supported by AI

Key difference between liquid resist and dry film resist lies in their **form** and **application method**:







Feature	Liquid Photoresist	Dry Film Photoresist
Form:	Liquid	Solid film
Application Method:	Spin coat, spray, dip	Lamination (heat and pressure)
Surface Compatibility:	Flat and complex surfaces	Flat surfaces only
Resolution:	Higher	Moderate
Common Use:	Semiconductor, microfabrication	PCB / PCM manufacturing
ADVANTAGES	• Can coat non-flat or complex surfaces • Offers high-resolution patterning capabilities • Very thin (1 µm) coating thicknessess possible	• Uniform thickness • No liquid handling (→„cleaner“) • Easier for batch processing and automation
DISADVANTAGES	• Requires precise control during coating (e.g. spin speed, viscosity) • Larger risk of contamination • Larger risk of thickness variation	• Limited to flat surfaces • Typically lower resolution

Content supported by AI

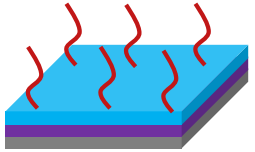
IMAGING OF LIQUID AND DRY FILM PHOTORESIST

1) Substrate Preparation

Goal / Purpose:
- Clean surface for resist application

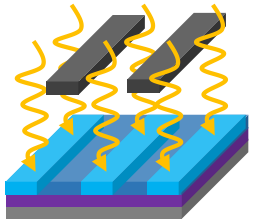
2) Photoresist Application

Goal / Purpose:
- Coat the surface with uniform photosensitive layer



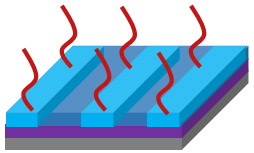
3) Soft Bake (Prebake)

Goal / Purpose:
- Remove solvents,
- improve adhesion



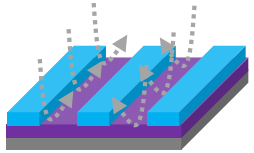
4) Exposure

Goal / Purpose:
- Create pattern
- Change resist solubility through light exposure



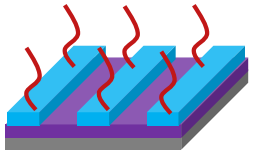
5) Post-Exposure Bake (Optional)

Goal / Purpose:
- Improve image stability



6) Development

Goal / Purpose:
- Reveal pattern by dissolving resist
- Remove exposed (positive) or unexposed (negative) areas



7) Hard Bake (Optional)

Goal / Purpose:
- Strengthen resist to withstand etching chemicals

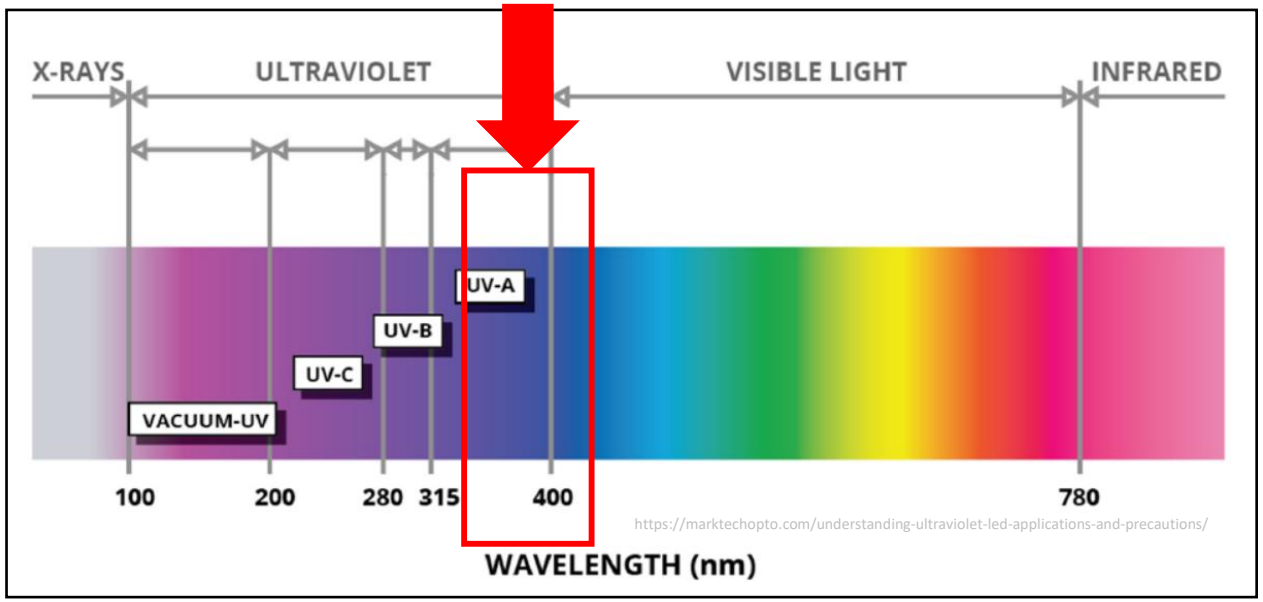
8) Chemical Etching

Goal / Purpose:
- Chemically remove exposed metal/material

9) Photoresist Stripping

Goal / Purpose:
- Remove remaining photoresist

LIGHT SOURCE - UV SPECTRUM



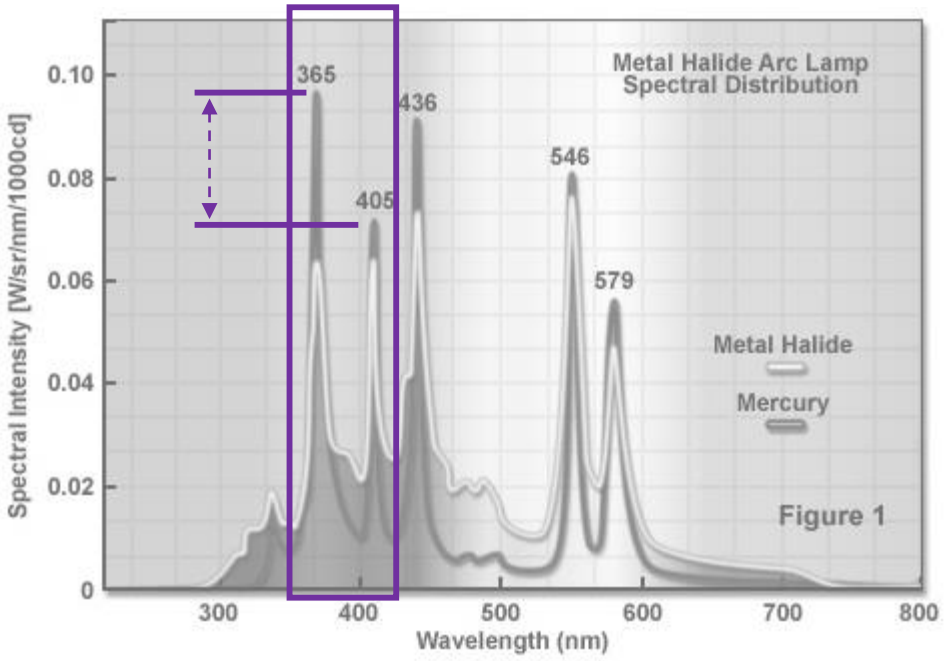
The i-line in UV spectrum corresponds to a wavelength of 365 nm, while the h-line corresponds to a wavelength of 405 nm. Both are used in photolithography, a process that uses UV radiation to expose and pattern photoresists. I-line (365 nm) and h-line (405 nm) are also part of the broadband UV spectrum (350-450 nm) which includes the g-line at 436 nm.

Elaboration:

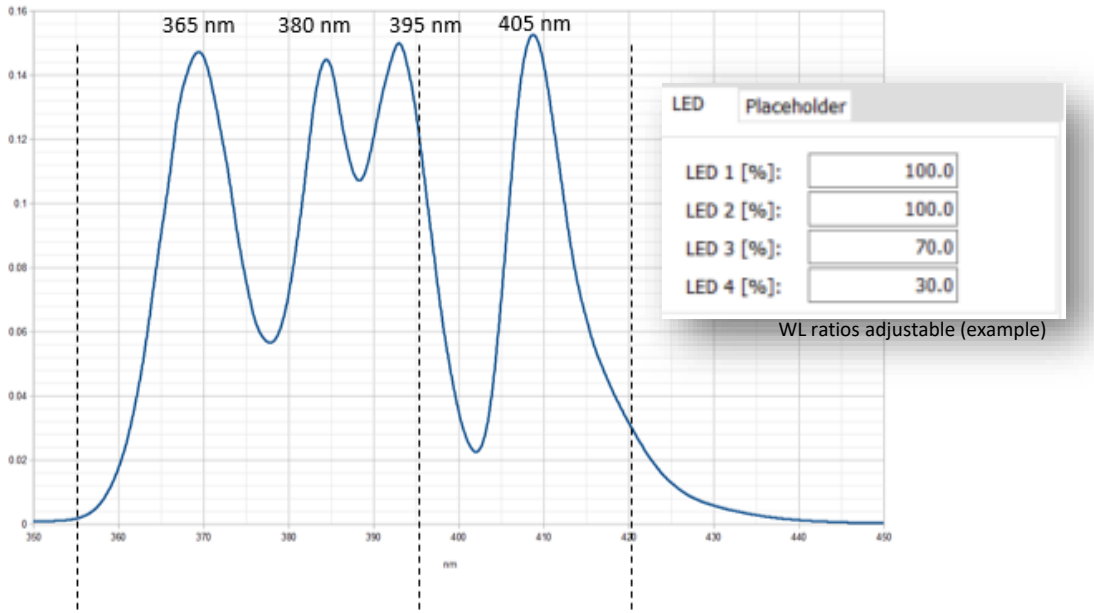
- **i-line:** Represents a strong emission peak in the mercury spectrum at 365 nm.
- **h-line:** Represents another strong emission peak in the mercury spectrum at 405 nm.
- **Broadband UV:** This is a wider range of UV radiation, encompassing wavelengths including the i-line, h-line, and g-line (436 nm).
- **Photolithography:** This process utilizes these UV wavelengths to expose and develop photoresists, which are light-sensitive materials used in the fabrication of microstructures like those found in semiconductor chips and other devices.
- **UV-LED Sources:** In recent years, UV-LEDs have emerged as alternatives to traditional mercury lamps for UV exposure in photolithography.

Aspect	Conventional Exposure (Lamp-based)	Direct Imaging (LED-based)
Light Source	UV lamp (e.g., mercury, metal halide)	High-intensity UV LEDs (often 365/385/405 nm)
Pattern Delivery	Uses photomasks to project patterns	Uses digital files to expose pattern directly
Exposure Mode	Full-field (entire mask area at once)	Pixel-by-pixel (laser or DMD mirror projection)
Energy Control	Broad spectrum; requires filtering	Narrow-band, energy-efficient, wavelength-tuned

IMPACT OF WAVELENGTHS



Source: https://zeiss-campus.magnet.fsu.edu/articles/lightsources/metalhalide.html



WL ratios adjustable (example)

Conventional Exposure tool:

- Peak = i-line (365nm)
- No possibility to adjust
- 365nm „cures“ top of resist
- „Closes“ top surface of resist
- Bottom not strongly polymerized

Multi-Wavelength DI-tool:

- Multiple peaks (e.g. 365/380/395/405 nm)
- Adjustable
- Find suitable parameter to „cure“ resist top to bottom
- Resist more homogenously polymerized
- Higher flexibility!

DIRECT IMAGING
DEVELOPMENTS: LIGHT SOURCE AND RESISTS

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Developments of the light source		Developments of Materials (Resist)
Schmoll DI Gen. 1 1 Wavelength Light source: **Diode laser** Wavelength: **405nm**	Market participant A-Model 1 Wavelength Light source: **Laser** Wavelength: **355nm**	**Standard** Resist (not specifically designed for Wavelength-Peaks) **LDI** Resist (**355 – 365nm**)
Schmoll DI Gen. 2 2 Wavelengths Light source: **LED** Wavelengths: **365 + 385nm**	Market participant B-Model 2 Wavelengths Light source: **Laser** Wavelengths: **375 + 405nm**	
Schmoll DI Gen. 3 4 Wavelengths Light source: **LED** Wavelengths: **365 + 385 + 395 + 405nm**	Market participant C-Model 3 Wavelengths Light source: **LED** Wavelengths: **365 + 385 + 405nm**	**DI** Resist (**broad bandwidth: 365 – 405nm**)
Schmoll Fineline 1 Wavelength Light source: **Lasercomp.** Wavelength: **h-line**	Stepper D-Model 1 Wavelength Light source: **Deep-UV** Wavelength: **i-line**	1) Existing Liquid films (mostly **i-line**), high energy 2) High-Res Dryfilm Resists (mostly **h-line**), lower energy

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SIDEWALL OBSERVATION

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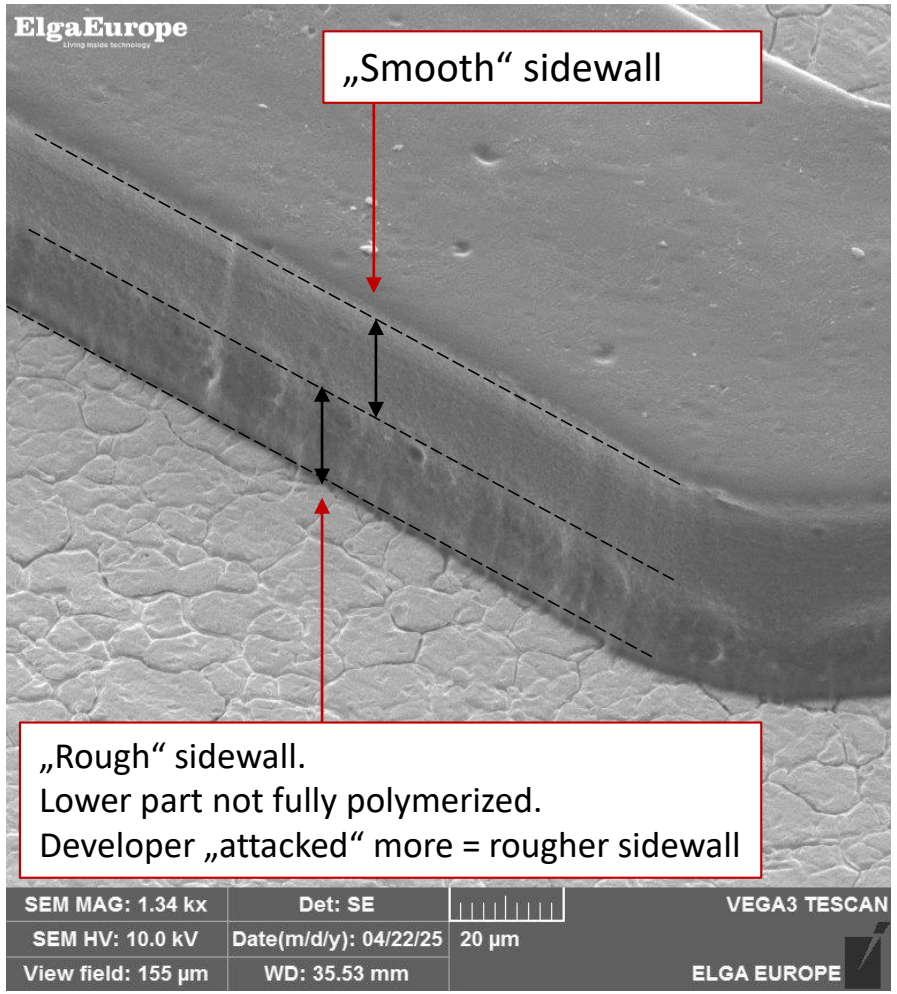
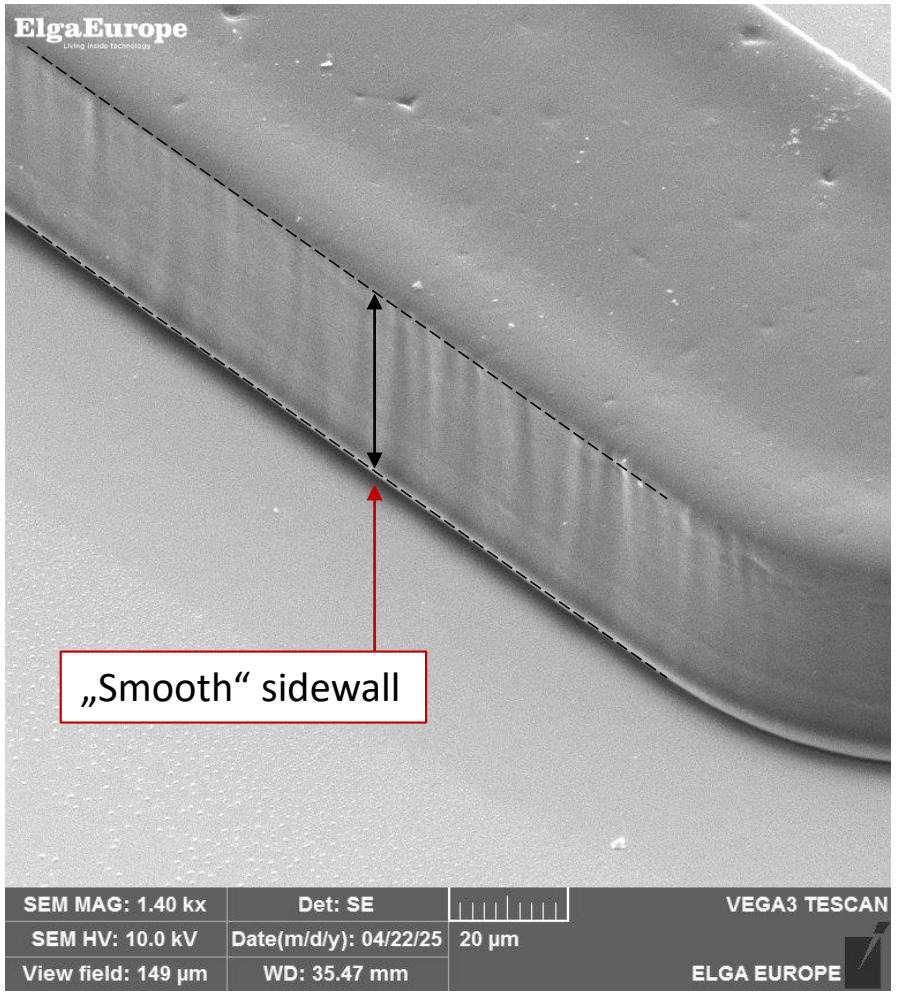


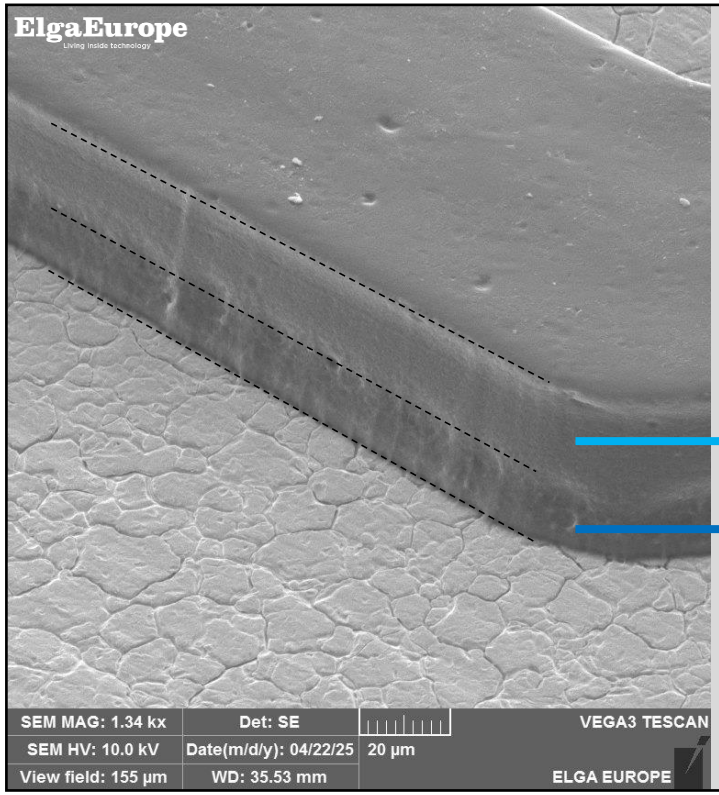
AF250E

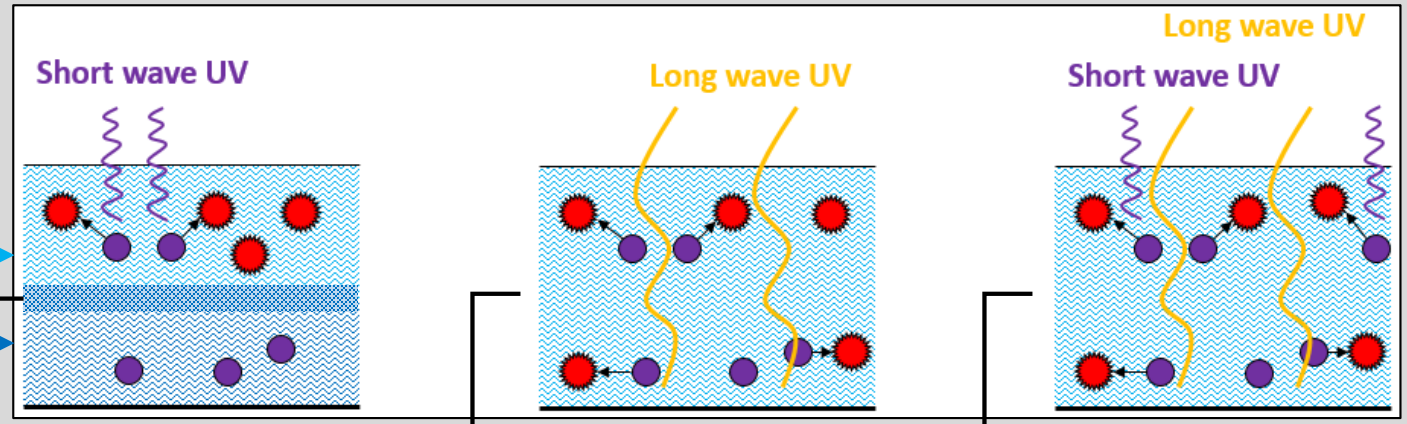


AM150 DI

Tests and SEM Pictures in collaboration with ElgaEurope Living inside technology

EFFECT OF WAVELENGTHS





Short wave UV can‘t reach at bottom. Excites the photo initiators **only near surface**.

Long wave UV **reaches at bottom**. Photo initiators excited, but higher energy required = longer time

Short wave UV excites photo initiators near surface.
Long wave UV excites photo initiators at bottom.
Overall resist imaged more **homogeneously**.

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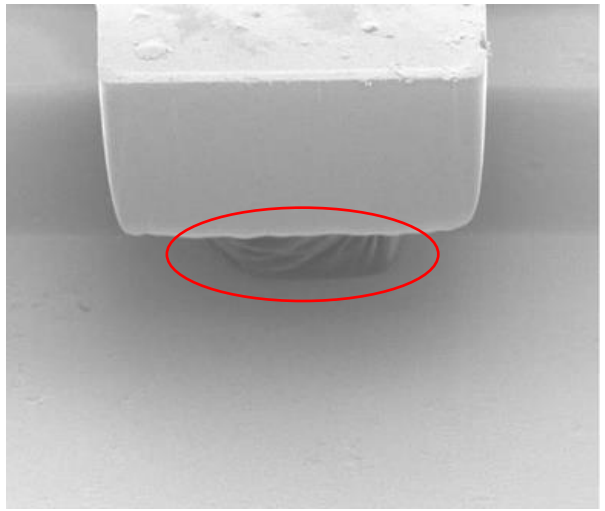
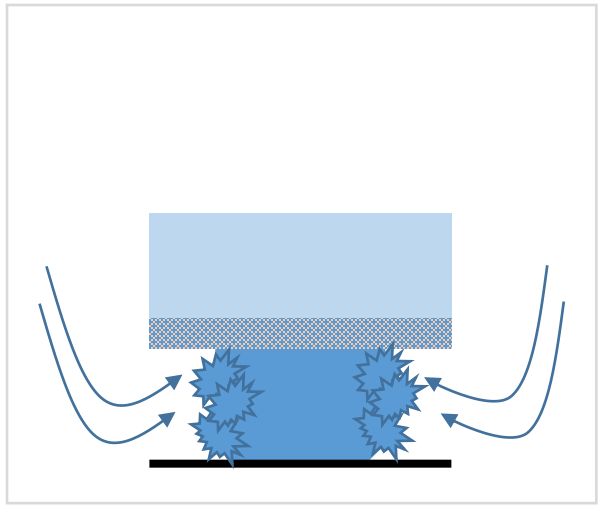
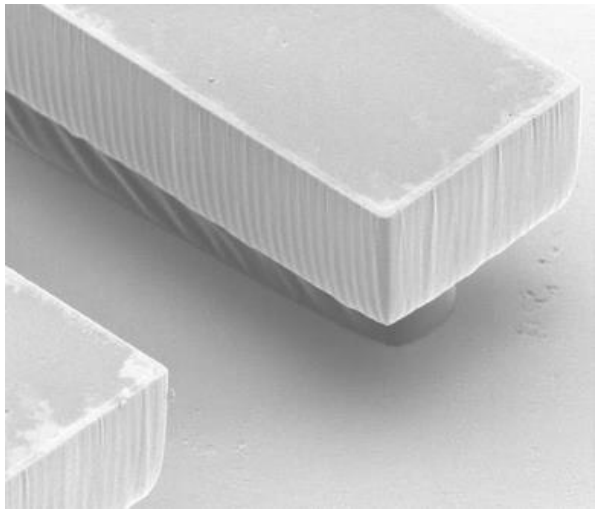
EFFECT OF WAVELENGTHS







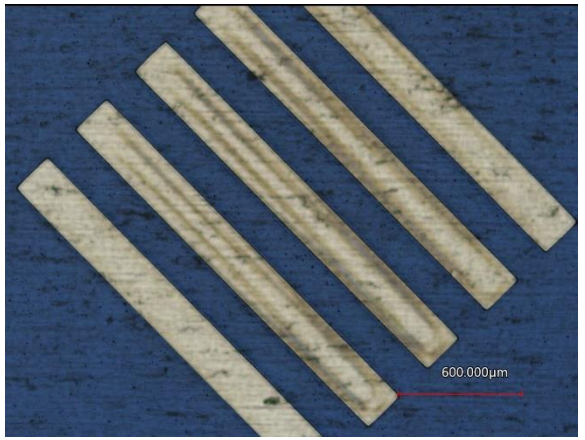
ÊFFECT OF WAVELENGTHS - TEST

„Triple lamination“: Resist thickness total = 120 µm

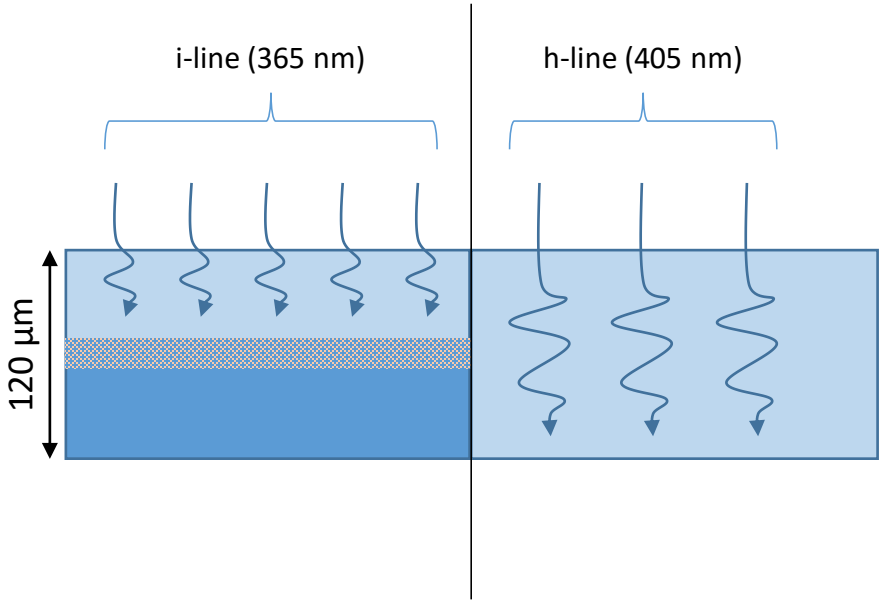
365nm

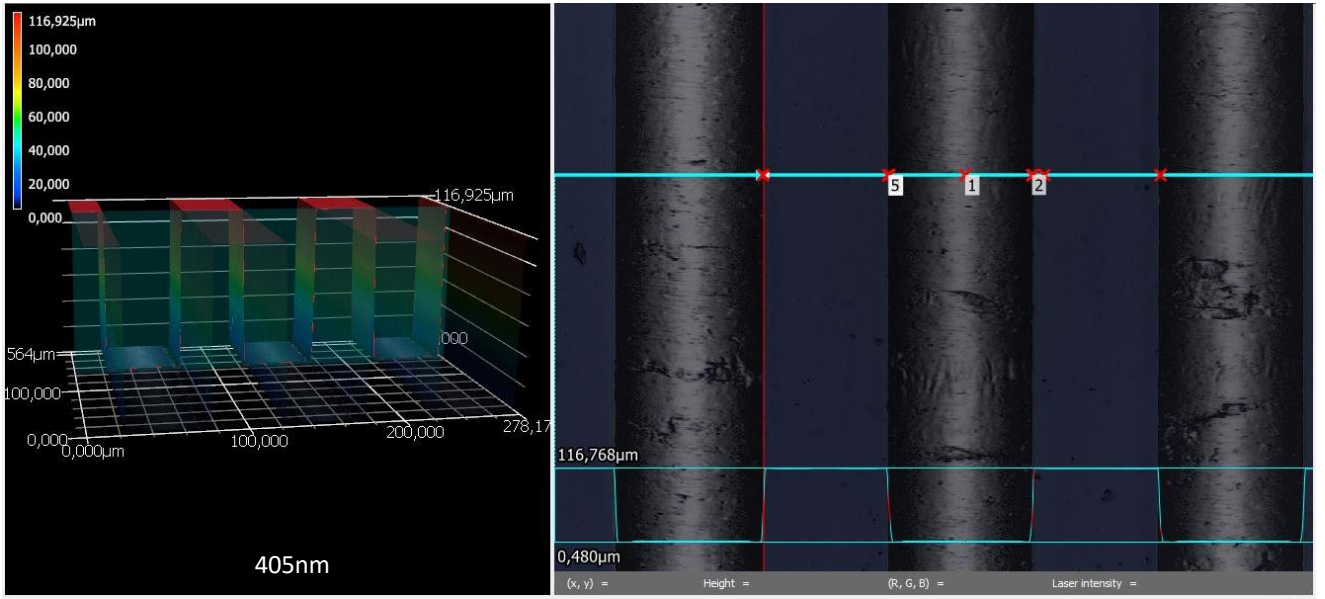
380nm

395nm



405nm





405nm

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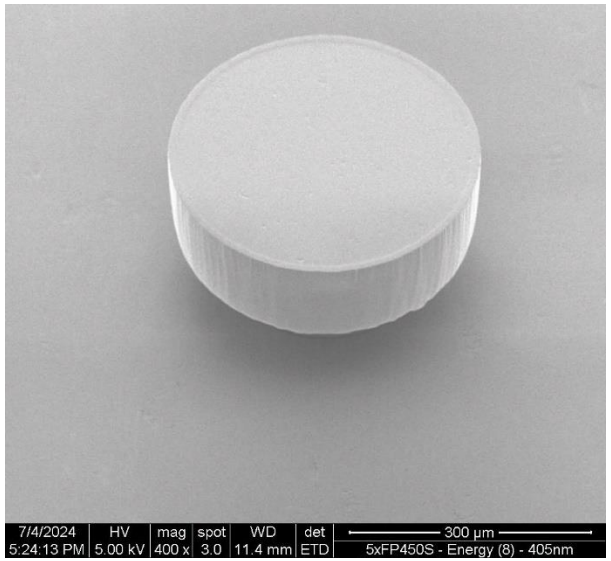
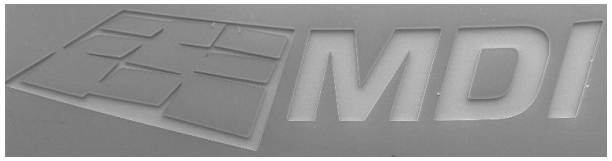
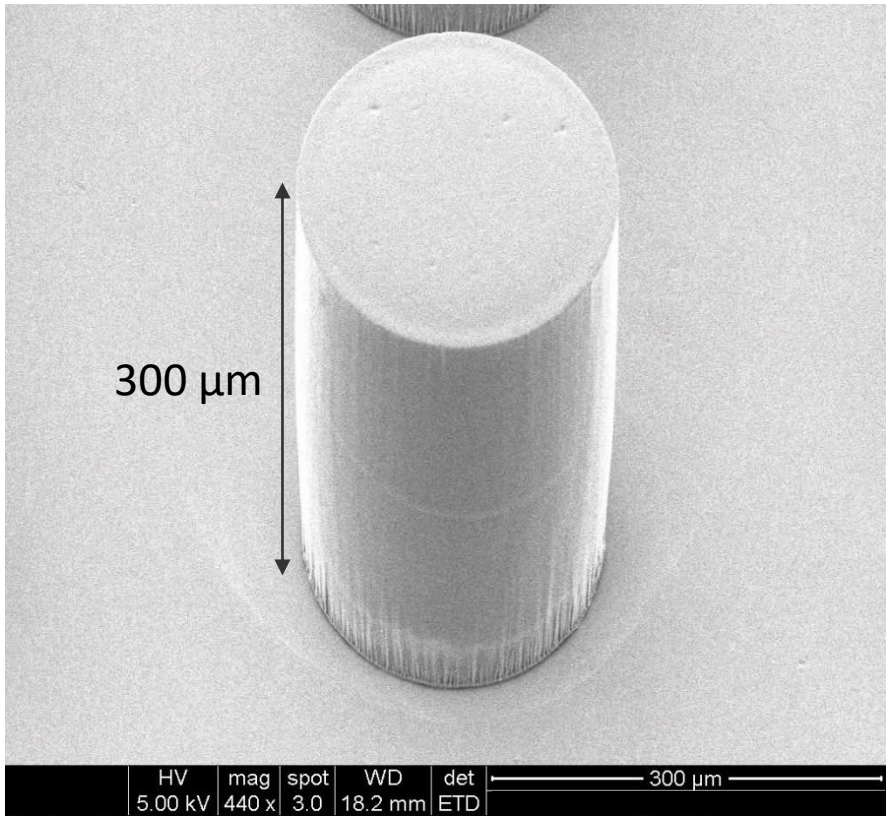
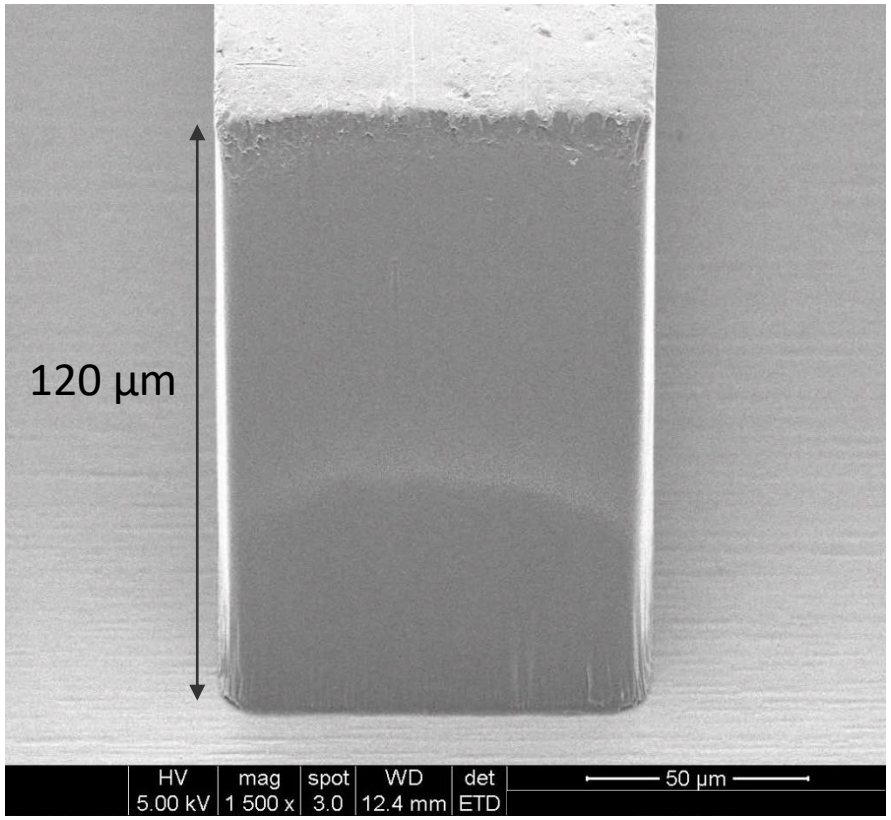
EFFECT OF WAVELENGTHS









PCM
MANY MATERIALS = MANY DIFFERENT SURFACES

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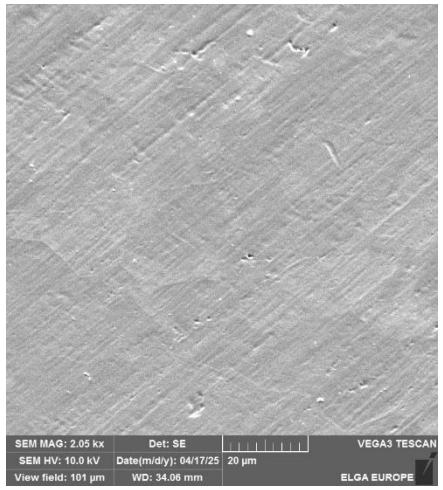
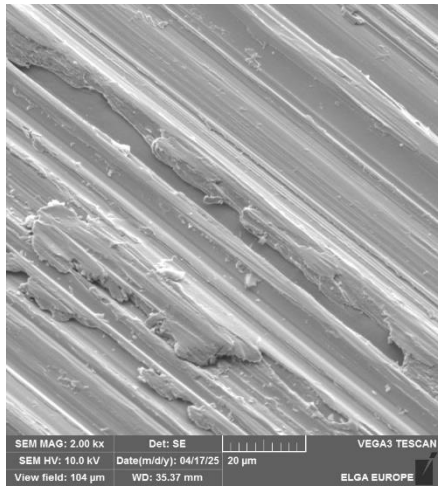
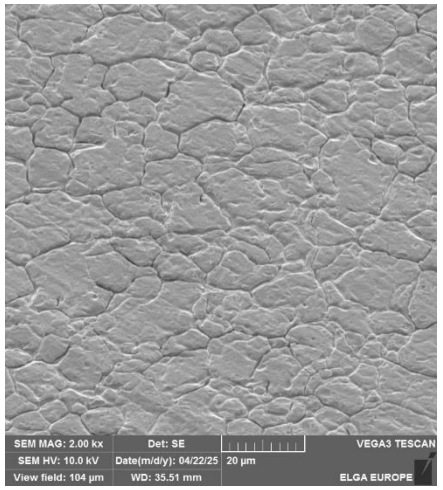
Tests and SEM Pictures in collaboration with ElgaEurope Living inside technology



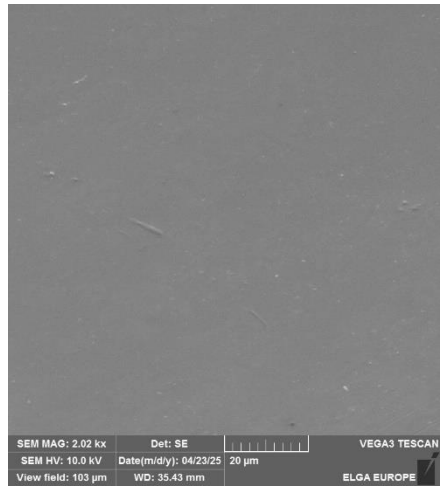
INOX BA MIRROR



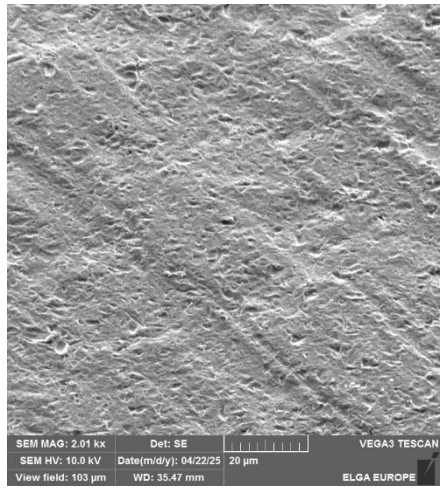
INOX SATIN



INOX 2B



INOX SUPERMIRROR



BRASS

Different Material & Surface treatment

+

Same Photoresist

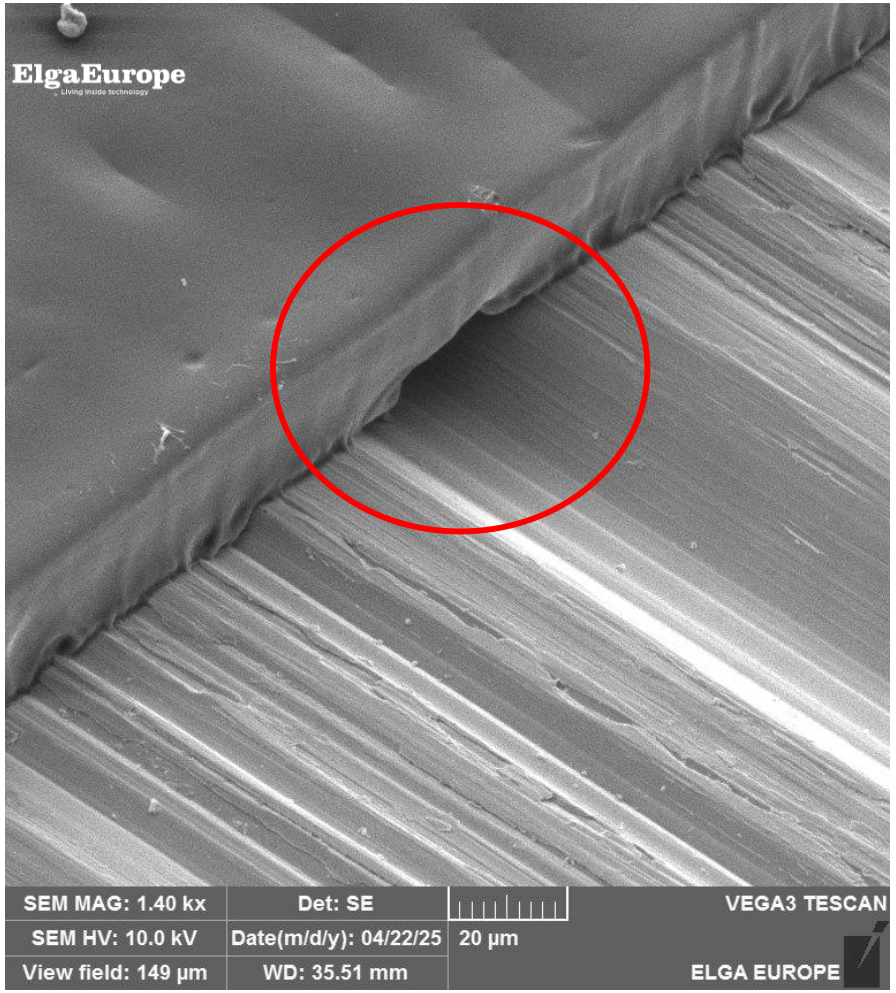
=

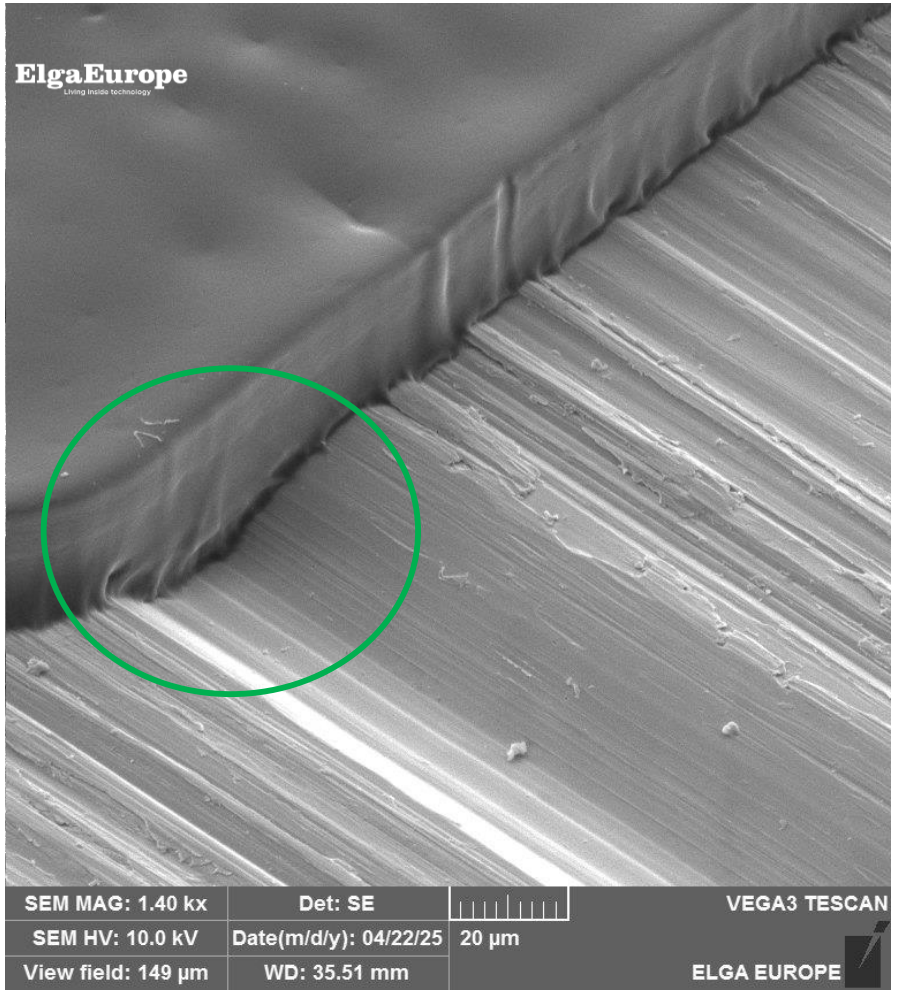
Different Recipe

Common Materials Used in Chemical Etching

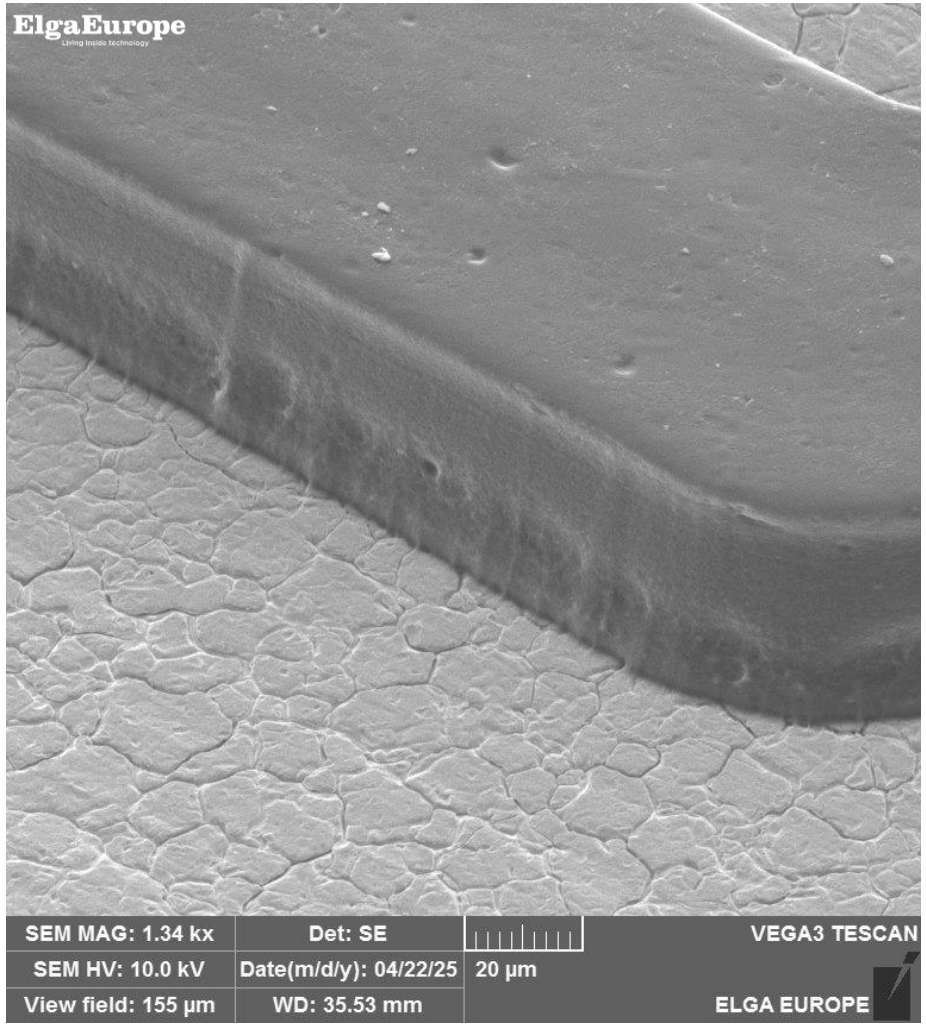
Material	Properties
Stainless Steel	Corrosion-resistant, strong, chemically etchable with ferric chloride
Copper	Highly conductive, easily etched, used with cupric or ferric chloride
Brass (Copper-Zinc alloy)	Good machinability, decorative finish, etches similarly to copper
Nickel	Hard, corrosion-resistant, precise etching with nitric acid or ferric chloride
Aluminum	Lightweight, conductive, etched with nitric acid mixtures
Titanium	Very strong, corrosion-resistant, etched with aggressive etchants (HF-based)
Molybdenum	High-temperature stability, difficult to etch, used with specialized etchants
Phosphor Bronze	Good conductivity and wear resistance
Beryllium Copper	Excellent electrical properties and fatigue resistance
Inconel (Nickel Alloys)	Heat and oxidation resistant, used in harsh environments

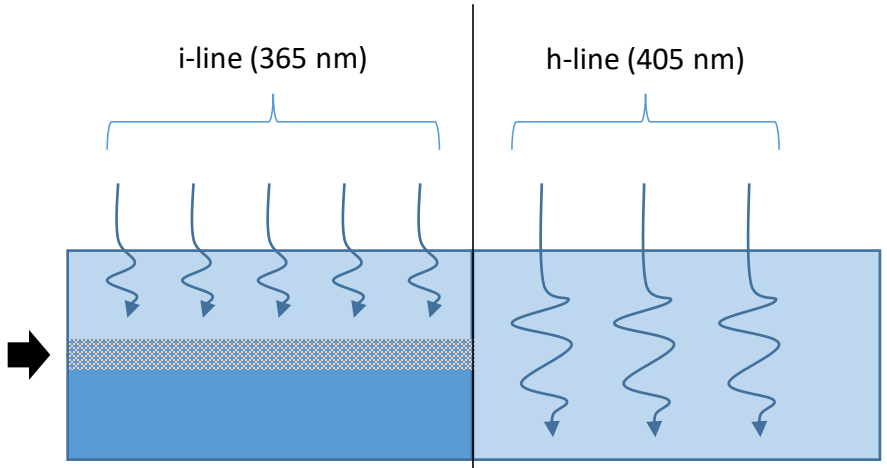
MDI
EFFECT OF WAVELENGTHS





SUMMARY: EFFECT OF WAVELENGTHS



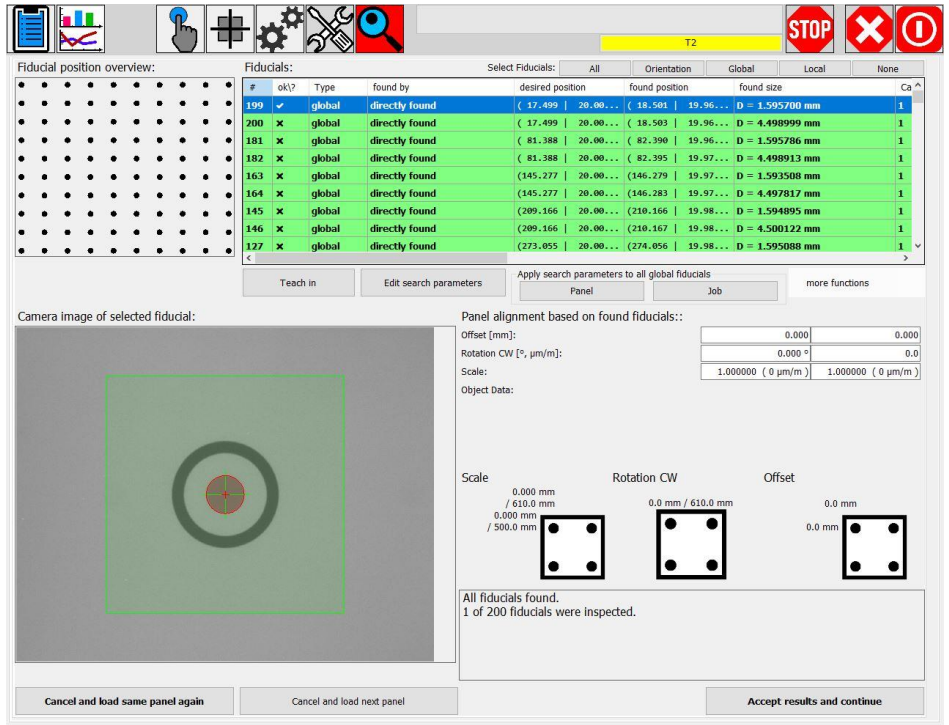


Resist surface „closes“ with lower wavelength; „blocks“ higher wavelength from penetrating through to the bottom for full polymerization.

Result: Bottom part „weaker“ against developer.
Leads to rougher sidewall
(and undercut)

At higher wavelength, the resist is imaged more homogeneously across complete depth. Fuller polymerization leading to smoother sidewall, as developer „attacks“ equally.

MDI
RESIST IMPACT ON ACCURACY



Screenshot: Schmoll MDI User-Interface

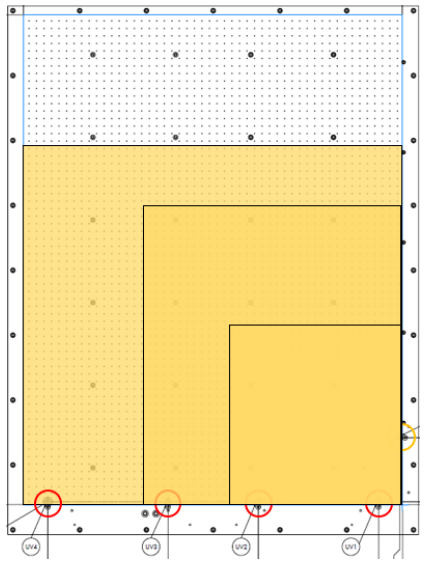
Many different alloys, stainless steels, …

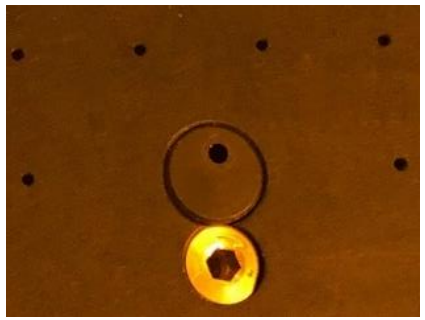
- *… have very different surfaces*
- *… have different reflection*
- *… have different thermal characteristics*
- *… behave differently during lamination* *(material „moves“ more than others)*

→ Image control
(through optimum recipe + accurate alignment)

→ Avoid different profile when etching one side more than the other

COLOR CHANGE ON RESIST FOR UV-MARKER



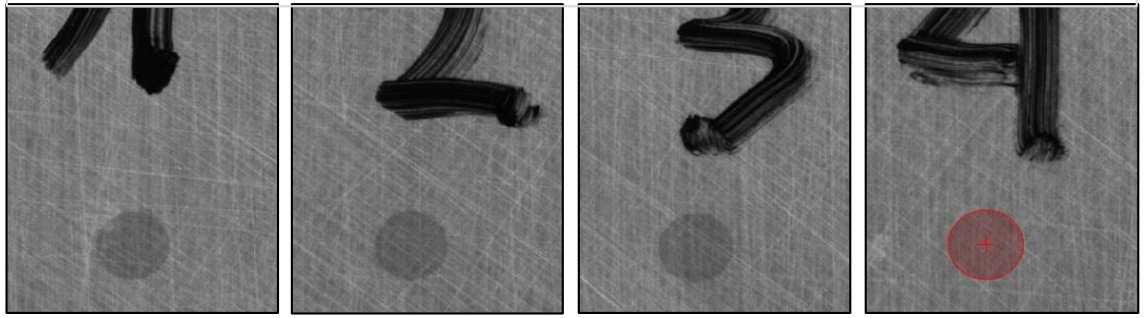


RESIST A

DuPont MM120i

*Photo results with phone camera

*Photo results with registration camera on machine



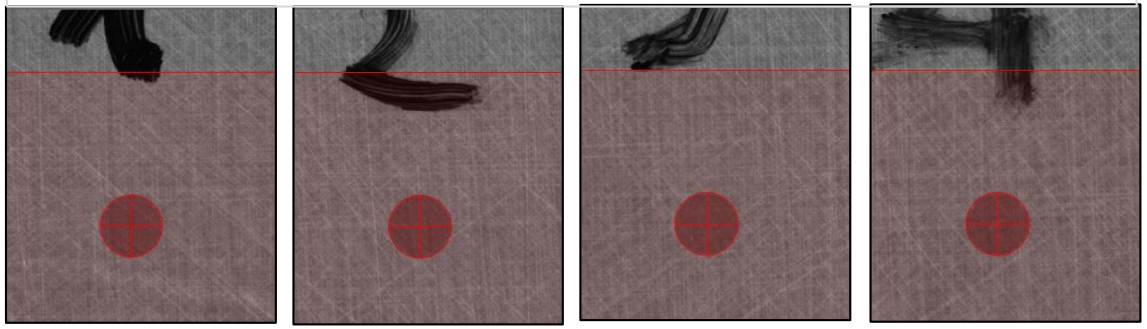
1 time exposure | 2 times exposure | 3 times exposure | 4 times exposure

RESIST B

Eternal E9220

*Photo results with phone camera

*Photo results with registration camera on machine



1 time exposure | 2 times exposure | 3 times exposure | 4 times exposure

MDI
MULTI-WAVELENGTH SOLUTION WITH DI

„All Resists can be exposed with DI“

„Exchanging Exposure machine does not require change of resist type“

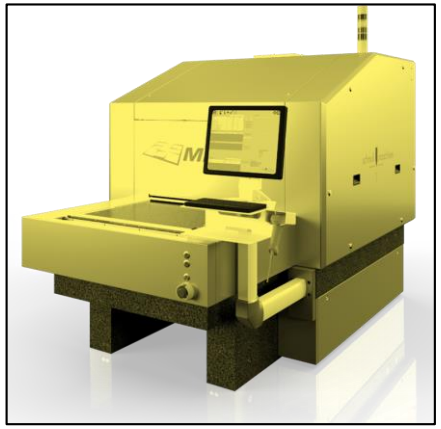
„Right exposure for right material“

„Right Recipe for right material!“

Correct choice of Direct Imaging technology can provide a real solution!

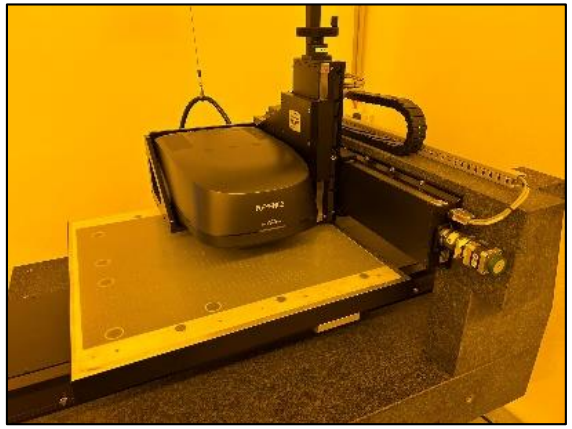
MDI
TEST CAPABILITIES @SCHMOLL

Spin Coater & Developer



MDI Imager

Developer (Photoresist)



Laser Microscope stage

- Demo Machine (available with different Photohead resolutions)
- Developer
- Laser Microscope (stage)
- Spin coater for liquid resist
- Developer for liquid resist
- Hot plate
- Equipment to prepare Cross-Sections
- Diverse Resist materials (different thicknesses; standard and **high resolution**)

Convince yourself – make a test

THANK YOU


schmoll maschinen
...one step ahead.
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THANK YOU FOR YOUR ATTENTION