

## Green ICT hub for resource-optimized electronics production

# Substitution of N-methyl-2-pyrrolidone for semiconductor technologies

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### 1 Motivation

N-methyl-2-pyrrolidone (NMP) is a commonly used solvent in the semiconductor industry. This chemical enables the precise structuring of thin layers (lift-off process) and the cleaning of surfaces (resist stripping), which is particularly important to ensure the quality and performance of semiconductor components.

Since 2020, the use of NMP has been restricted in accordance with XVII of the REACH Regulation. NMP is classified as toxic for reproduction and can harm the unborn child.

For this reason, there is great interest in substituting the material.

### 2 NMP alternatives

At Fraunhofer IPMS, NMP has proven itself as a solvent for two technologies for the removal of photoresists.

The NMP replacement product should meet the following requirements:

- Removal of positive and negative coatings
- Low hazard classification
- Suitable for semiconductor applications
- No etching of the layers to be cleaned (Si, Poly-Si, SiO<sub>2</sub>, Al, AlSiCu, Al O<sub>23</sub>, Ta, Ta O<sub>25</sub>)
- Product can be removed without leaving any residue
- Follow-up cleaning with IPA and/or DI-H<sub>2</sub>O possible.
- Operating temperature: RT - 65 °C
- High flash pct. >60 °C; High boiling pct. >90 °C, Melting point <10 °C
- Suitable for use in the manual wet bench
- Material compatibility (stainless steel, PE-EL PFA, FFKM)
- Suitable for ultrasonic applications

After extensive research, only a few materials meet the above requirements:

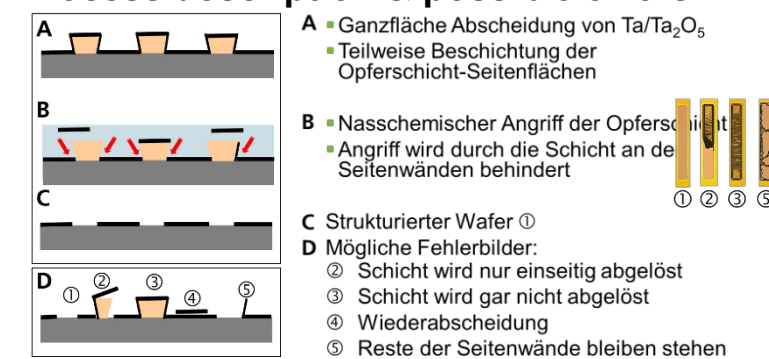
Product	Main ingredients	Process temp. [°C]	Fp. [°C]	Smp. [°C]	Sdp. [°C]
NMP	N-methyl-pyrrolidone	22, 40	86	-24	203
Product A	Aqueous mixture with ethers and alcohols	50	77	-16	97
Product B	Dimethyl adipate	50	100	-20	196-225
Product C	Dimethyl sulfoxide, diglycolamine (<10 %)	50	94	<10	189

### 3 Overview of technologies & results

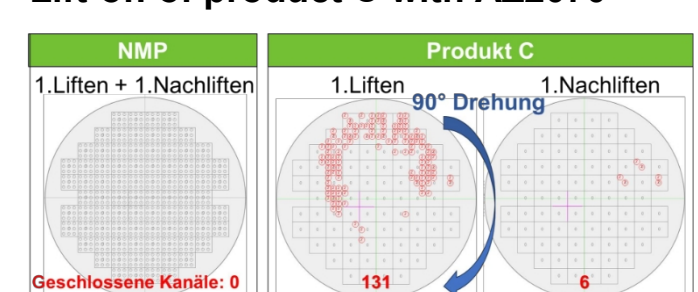
#### NMP technologies at IPMS

	Paint peeling	Lift-off
Photoresist type	■ Positive	■ Negative
photoresist	■ AR-PC5000/3.1 ■ (SPR 700-1.8 -> CMR substance since 2023)	■ nLof AZ2070 ■ AR-N2220
Layer thickness	■ 34 (17) µm	■ 7.5 µm
Process temperature (NMP)	■ 22 °C	■ 40 °C
Wafer material	■ Si, USG, Al O <sub>23</sub> , AlSiTi	■ Ta, Ta O <sub>25</sub>
Process requirements	■ No movement, ultrasound or spinning process	■ Ultrasound support possible
Process	■ NMP ■ IPA + IPA ■ DI-H <sub>2</sub> O high-flow flush ■ Dry in the N <sub>2</sub> river	■ NMP ■ IPA ■ DI-H <sub>2</sub> O Quick dump process ■ Centrifugal process
Requirements	None(s): ■ Paint residues ■ Damage to the structures ■ Influencing the mirror reflection ■ Bonding ■ Influence on movable structures	■ Open structures  None: ■ Paint residues ■ Open structures ■ No damage to the structures

#### Process description & possible errors



#### Lift-off of product C with AZ2070



#### Defect density during paint stripping of product B with Resist SPR700-1.8

Remover	Substrate	Al O <sub>23</sub>	USG	Si
NMP		3547	231	569
Product B after parameter adjustment (paint thickness, process time and temperature)		~3500	276	488

#### Overview of the results

Process	Paint peeling				Lift-off			
	Defects		Roughness & reflection		Open structures		Paint residues	
Resist	AR-PC5000	SPR 700-1.8	AR-PC5000	SPR 700-1.8	AZ2070	AR-N2220	AZ2070	AR-N2220
NMP	😊	😊	😊	😊	😊	😊	😊	😊
Product A	-	😞	-	😊	😊	-	😊	-
Product B	😊	😊	😊	😊	😞	😞	😞	😞
Product C	...	-	...	-	😊	...	😊😊	...

### 4 Outlook

For a final conversion of both processes to a different product, it is necessary to test further NMP alternatives or product C for paint stripping and/or to further adapt the technological processes.