Structuring Ceramics Using Lithography

A direct lithographic way to ceramic microstructures

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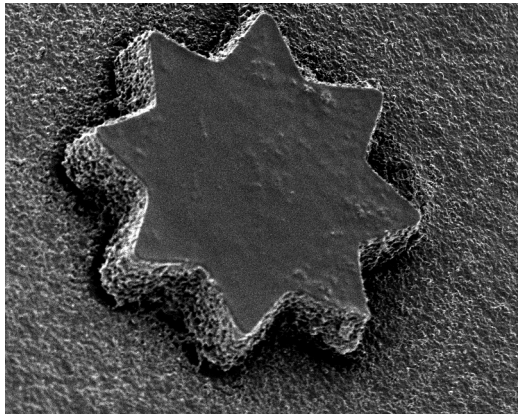


IMTEK

Outline

Ceramics in Microsystem Technologies

The lithographic process

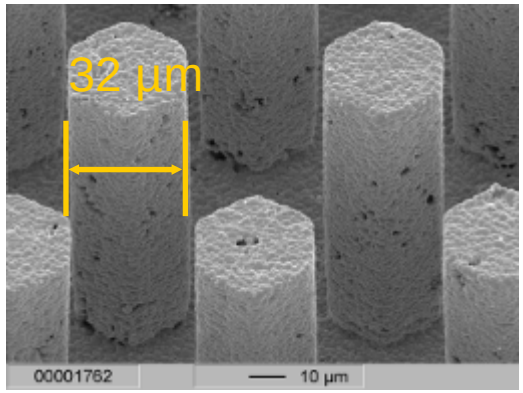
Results

Summary

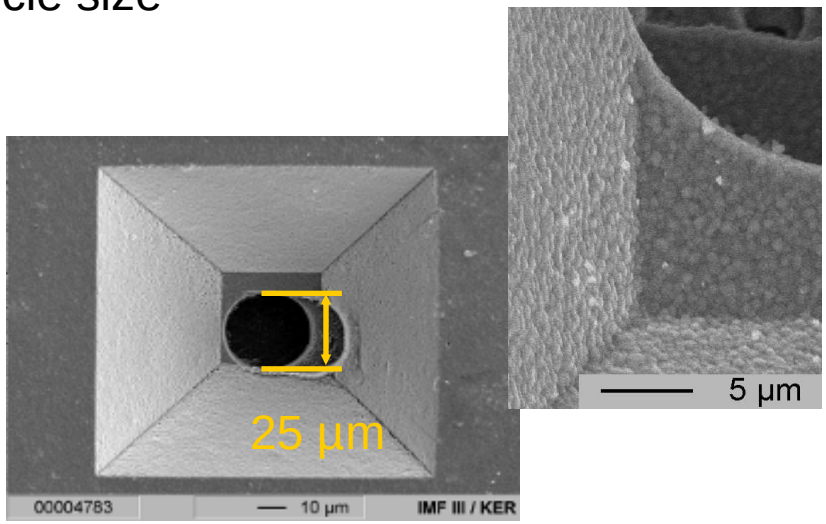
Ceramics in Microsystem Technologies

Challenges

- improved surface roughness
- smallest feature depends on particle size



Centrifugal cast sensor array (PZT)



Injection molded ink jet nozzle (ZrO_2)

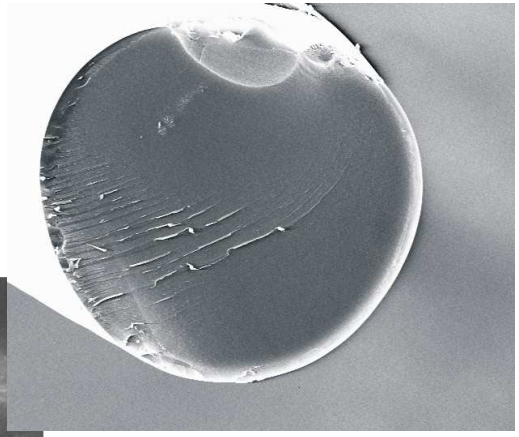
Applications

e.g. micro gear components, micro reactors, mold inserts…

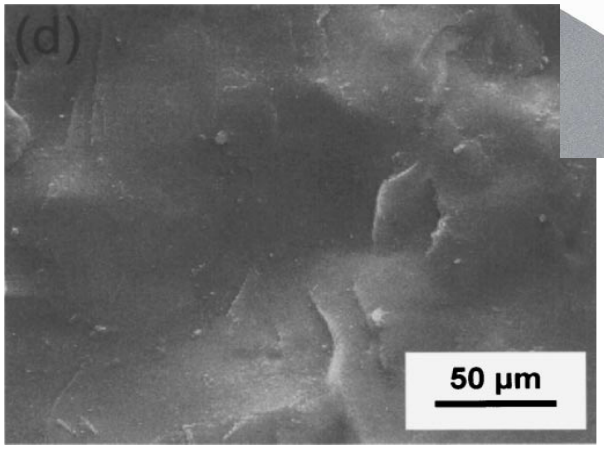
Polymer Derived Ceramics (PDC‘s)

Features

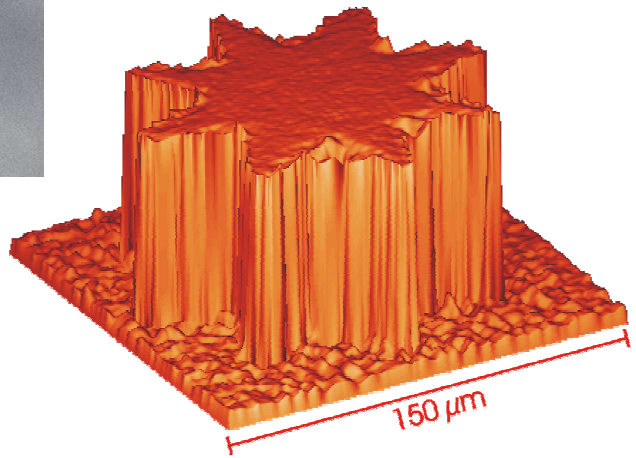
- smooth surfaces
- low sintering temperatures
- no sintering aids needed



SiC-Fiber ø = 0,6µm

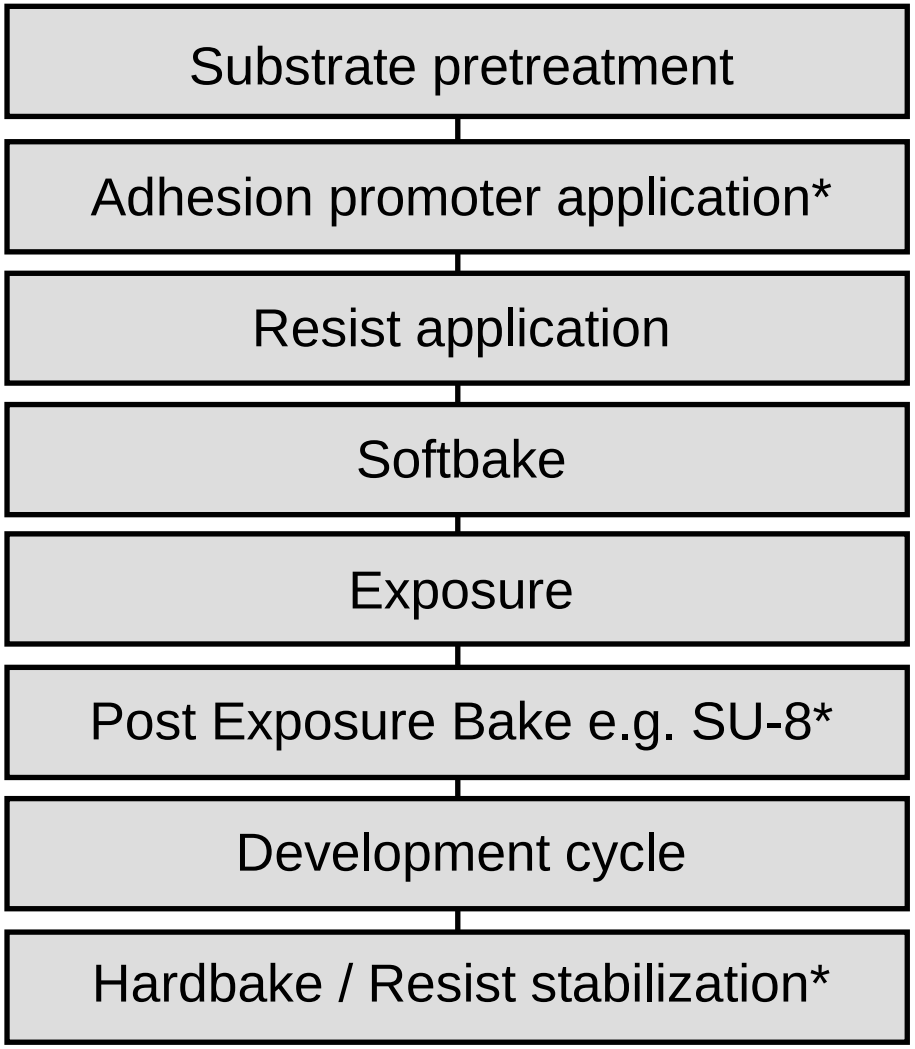


Coating



micro test structure topography

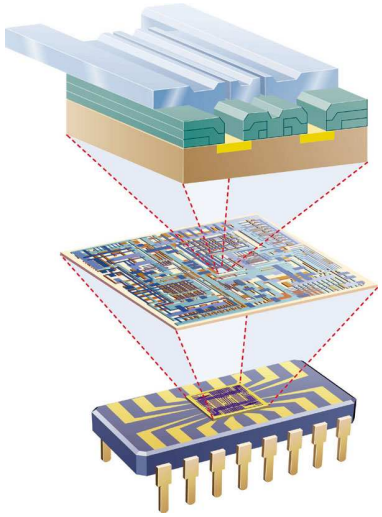
The lithographic process

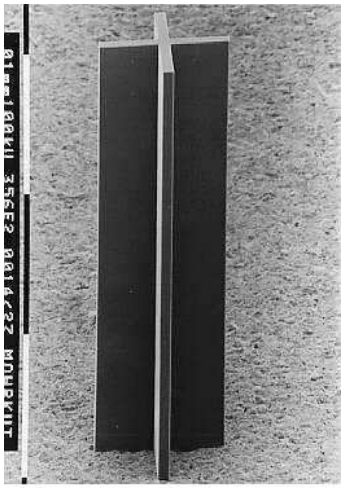


* = optional steps

Lithography application – Possibilities

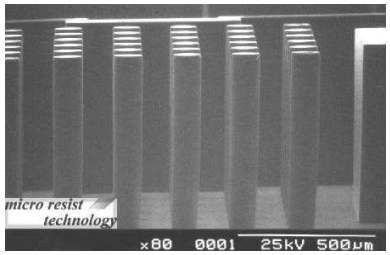
Microelectronics and Microsystem Technology



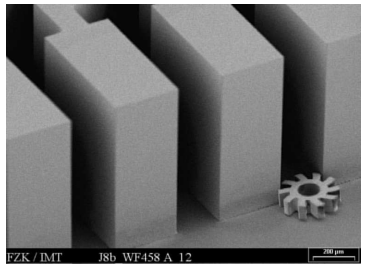


Bar structure 400 µm high, with parallel sidewalls.

negative resist



positive resist

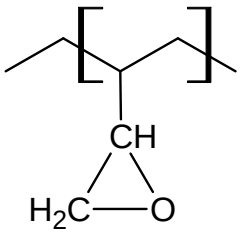


MEMS and MOEMS

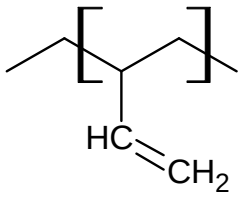
UV Lithography:	- smallest details	5 µm
	- structure height	100 (800) µm
	- aspect ratio	5
X-ray Lithography:	- smallest details	0.2 µm
	- structure height	1000 (3000) µm
	- aspect ratio	50

Lithography resist requirements

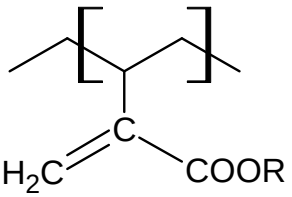
- **solid** aggregate state under ambient conditions; in case of UV-lithography an adjustable highly viscous state is acceptable
- **soluble** in standard aprotic organic solvents
- formation of **stable** films on substrate surfaces
- processability at ambient conditions for several hours, i.e. improved chemical **stability against** oxygen and **moisture**
- readily and selectively **soluble** in **developing** solvents
- **availability** and small batch variation
- high sensitivity against **photo chemical induced cross linking** throughout the presence of chromophoric side groups e.g.



Epoxy-



Vinyl-



Acryl-

Suited preceramic polymers so far

	NCP-200	SLM465012VP	Ceraset / VL20	ABSE
	Nichimen Corp.	Wacker	KiON Corp.	IMA Bayreuth Germany
solubility	+	+	+	+
stable films	+	+	-	+
sensitivity against moisture	0	+	+	++
developing	0	+	+	+
radiation sensitivity	UV / X-ray	UV / X-ray	UV /	not tested / - / X-ray
availability	-	-	+	+

- = not suited 0 = suited + = well suited ++ = best suited

M. Schulz et.al., *Adv. Eng. Mater.* 2004;
T. Hanemann et.al., *Adv. Eng. Mater. 2002*

X-ray dose screening – ABSE

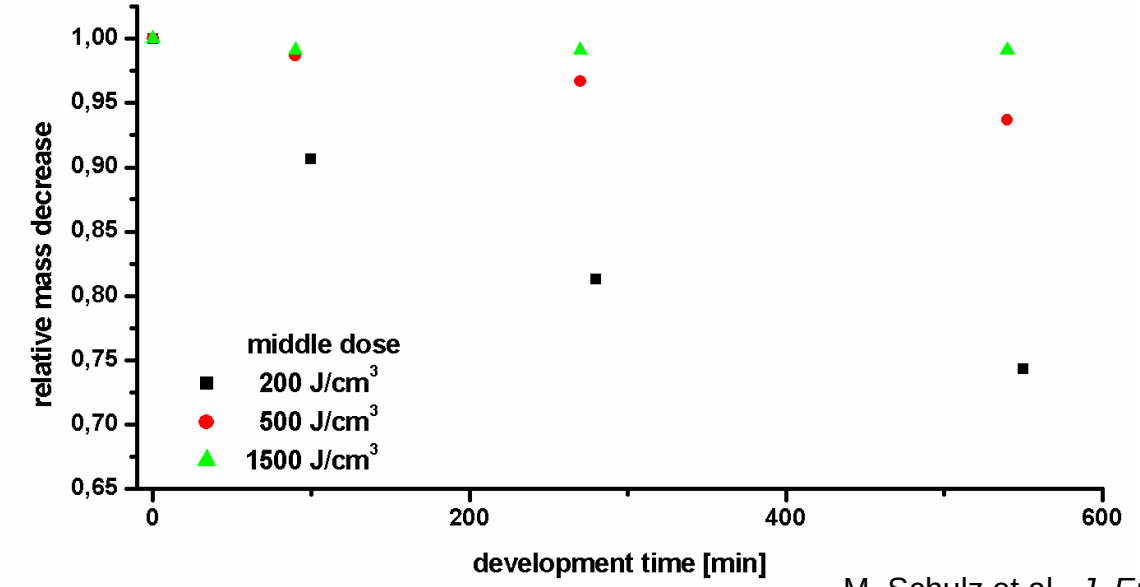
required X-ray bottom dose:

ABSE	500 – 1500	$J \cdot cm^{-3}$	negative resist

compared to:

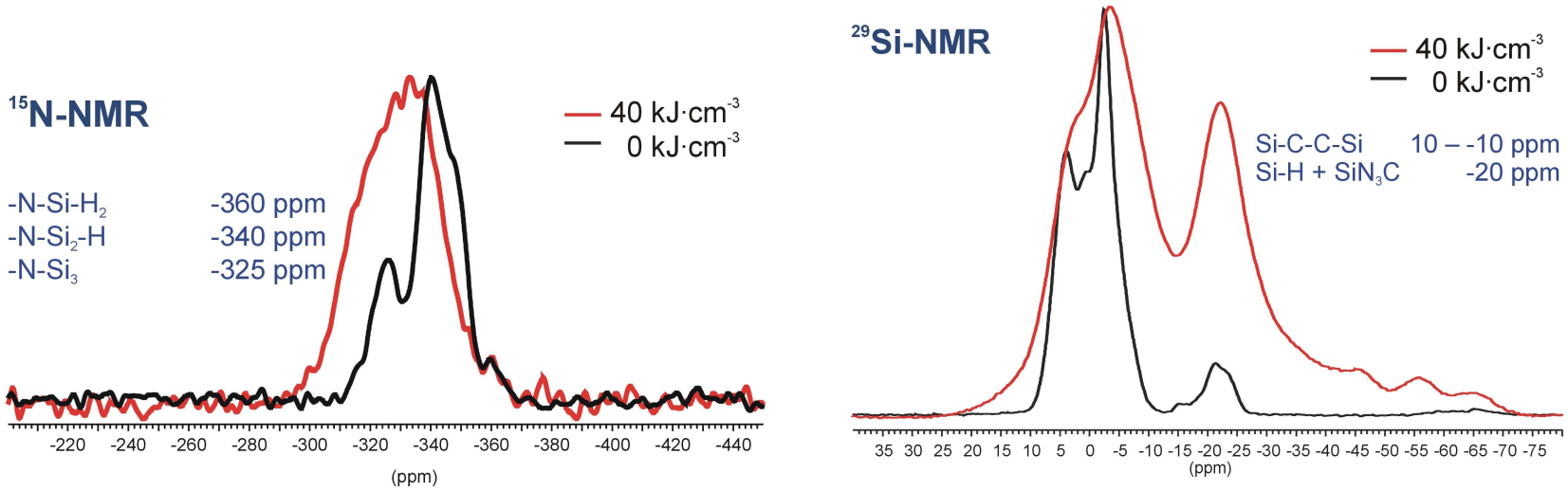
SU-8	15	$J \cdot cm^{-3}$	negative resist
PMMA	4000	$J \cdot cm^{-3}$	positive resist

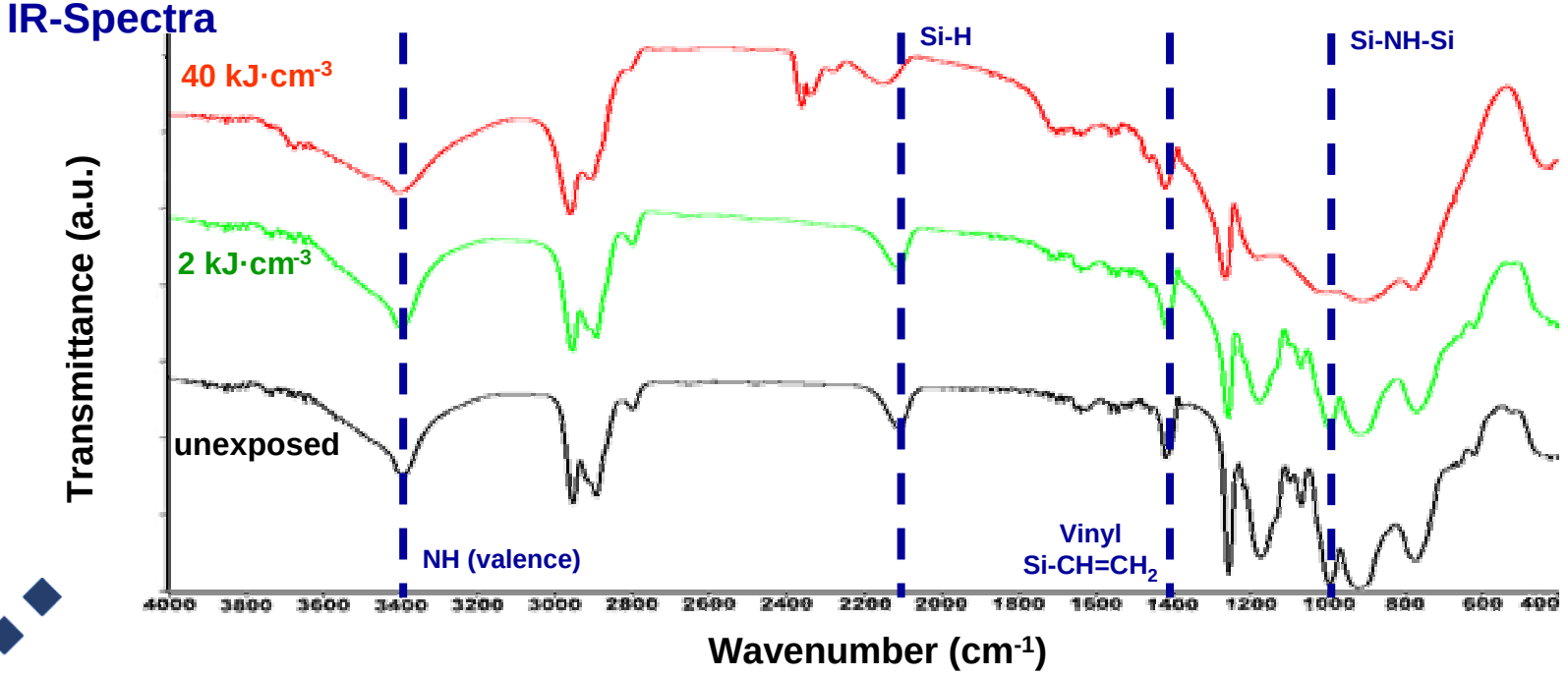
solubility of irradiated samples



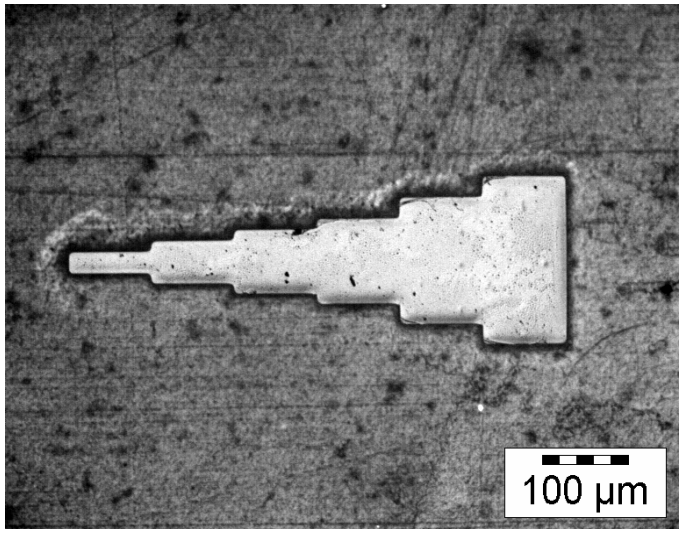
M. Schulz et.al., *J. Eur. Cer. Soc.*, 2004

X-ray induced crosslinking of ABSE



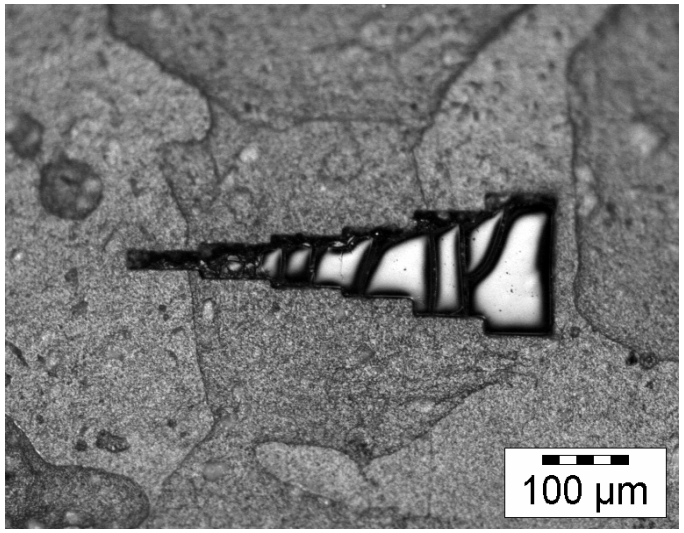


Micro test structures from pure ABSE

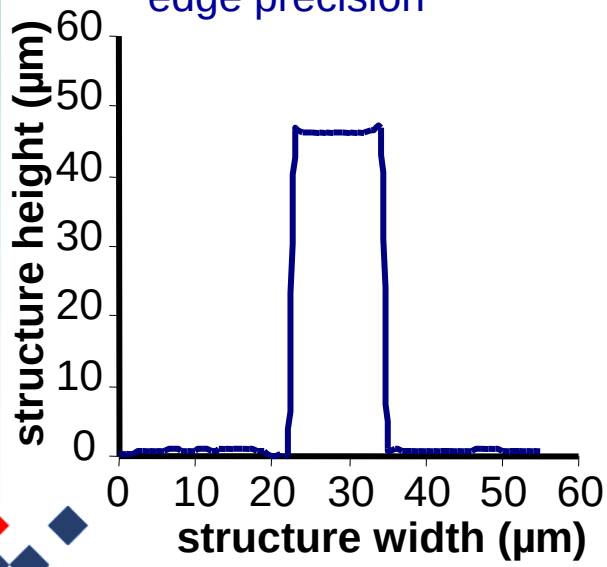


Pyrolysis

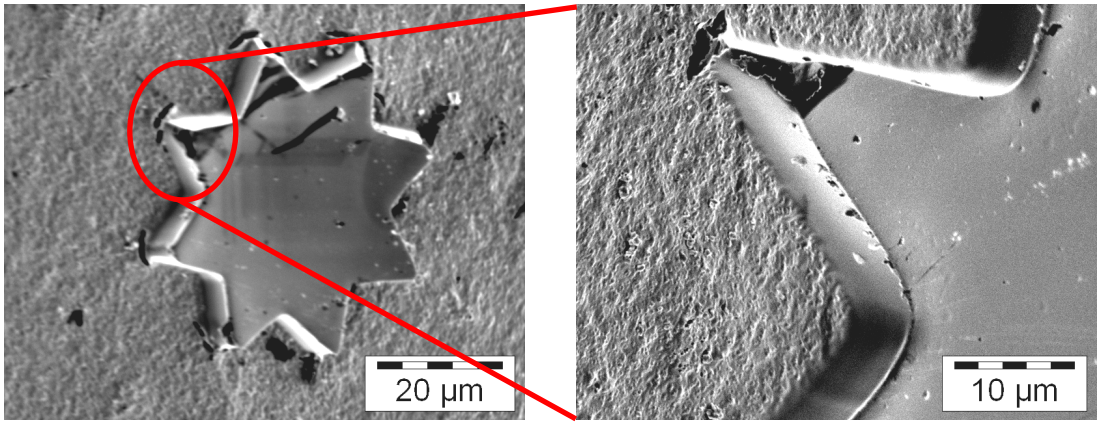
up to 1200 ℃



edge precision



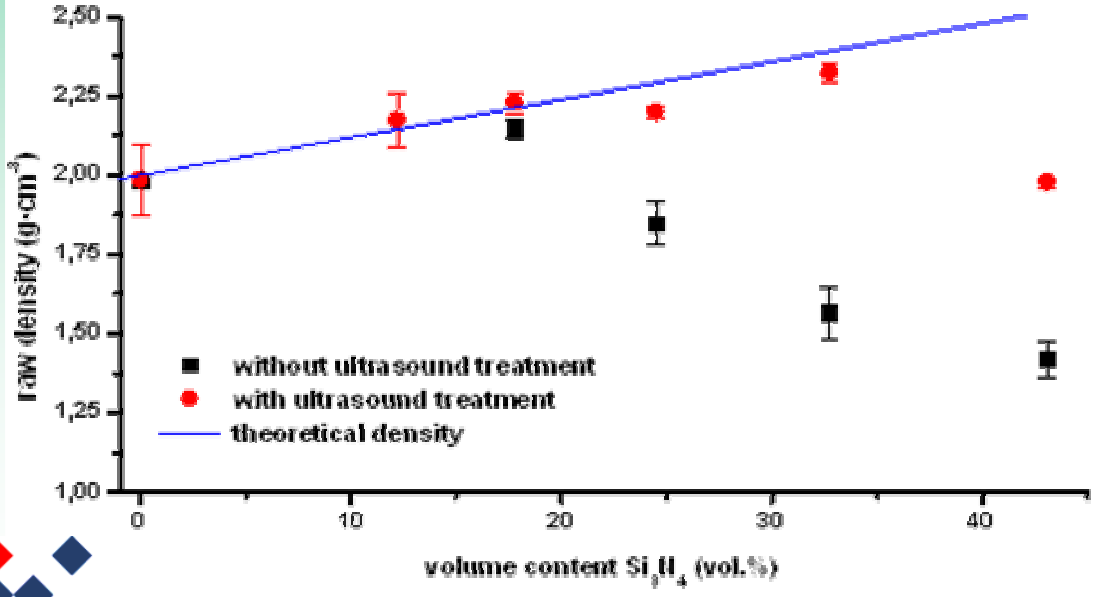
pyrolysis on native substrates



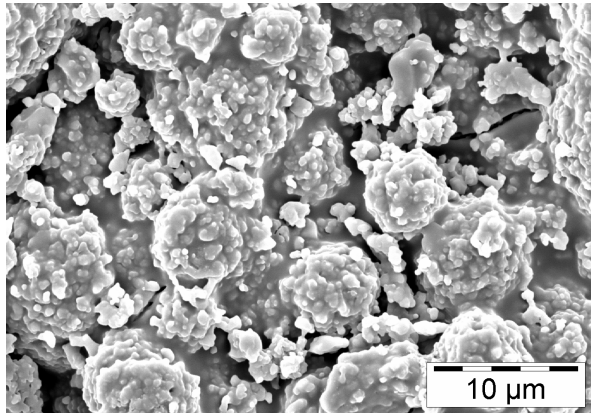
Processing of composites –
Influence of deagglomeration on pyrolysed samples

- Significant decrease of open porosity
- Improved density corresponding to the theoretical values
- Hardness up to 1068 ± 36 HV

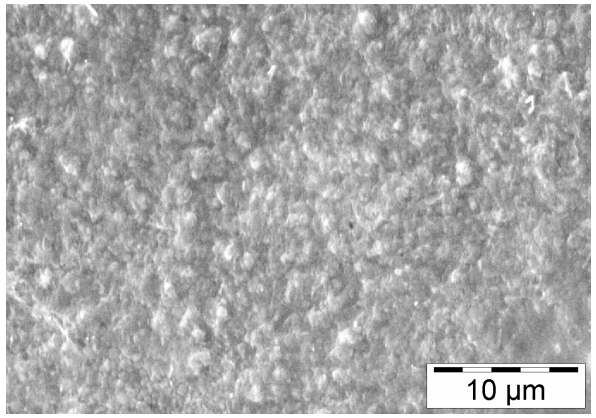
Raw density of pyrolysed samples



without ultrasound



with ultrasound

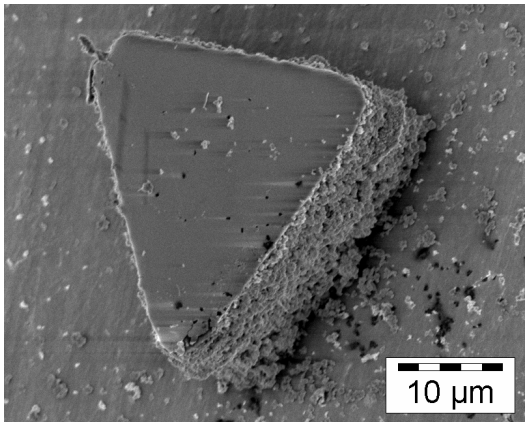


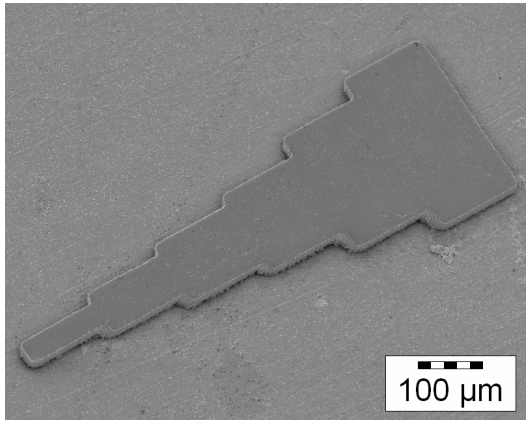
Si_3N_4 filler content: 25 vol.%
UBE SN-E10, d_{50}=0,5 µm

Micro test structures from powder filled ABSE

- high edge precision
- side wall roughness
- low surface roughness
- crack free pyrolysis

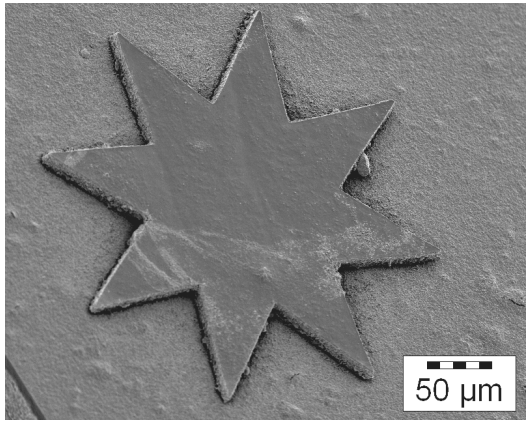
before pyrolysis

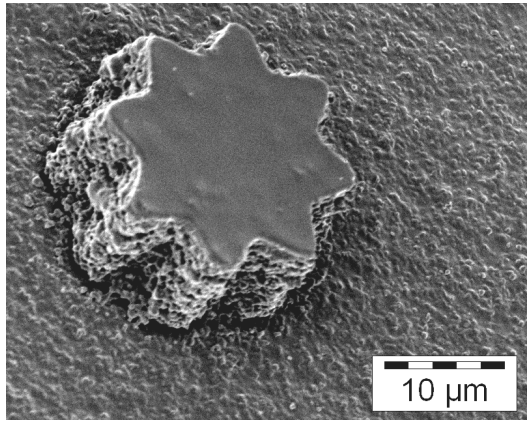


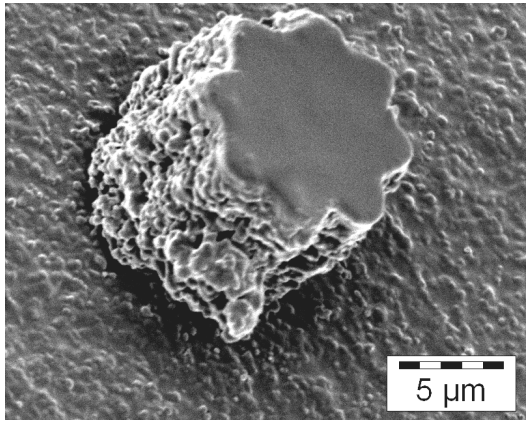


40 wt.% Si_3N_4 in the resist material

after pyrolysis

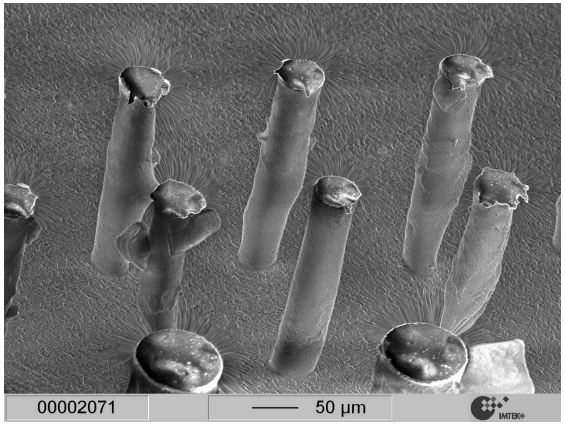






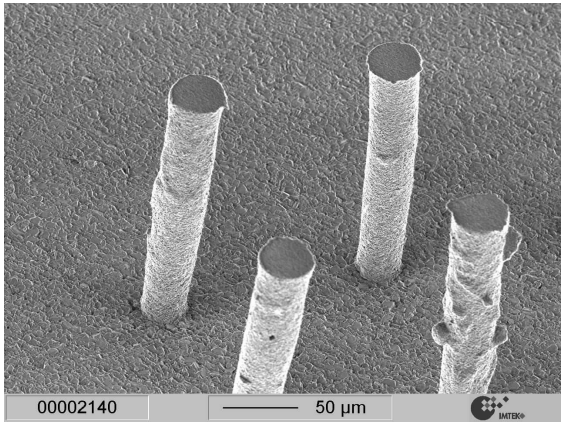
Other composites – standard resist material and ceramic powder

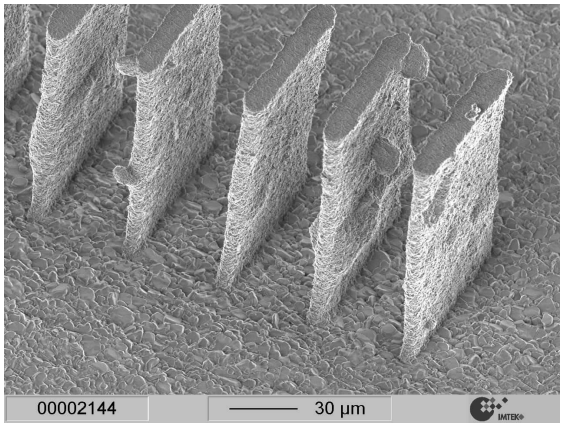
- dispersion of Al_2O_3-powder in SU-8 standard negative resist
- casting on alumina wafers
- X-ray lithography
- pyrolysis and sintering up to 1550 ℃



developed structure
height 360 µm, ∅ = 40 µm

sintered structures





length: 100 µm, width 10 µm
height: 160 µm

C. Müller et al., Microsystem Technologies 2005, in press

Summary

- The lithographic process allows for direct micro structuring of ceramic precursors
- Pyrolysis on native substrates enables crack free and dense micro structured parts
- Low surface roughness and high edge precision possible
- Lithographic structuring of composites possible
- Resolution limited mainly on particle size
- Smallest details of 5 µm were produced
- Resist thickness up to several hundreds of µm were structured

Acknowledgement

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