Melt spun aluminium for optical moulds

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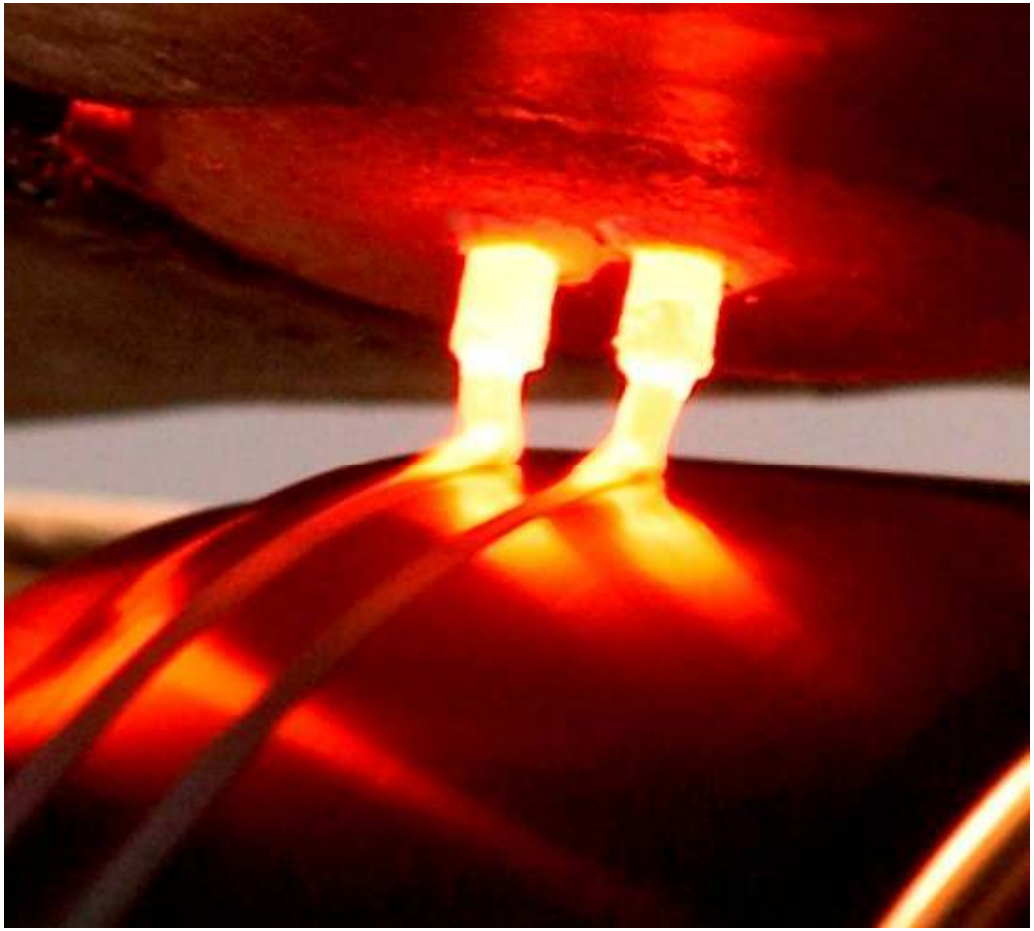
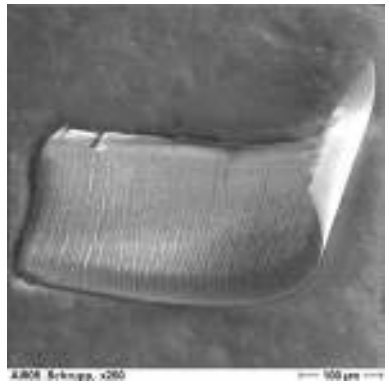


Summary of presentation during seminar:
Prozessketten zur Replikation komplexer Optikkomponenten
Bremen, Germany on 13 -14 nov 2008

RSA alloys for optics



Commercial opportunity:

• Due to increasing material demands, optical applications can be an interesting niche market for the fine grain sized RSA alloys

Technical challenges:

• In general:

– Develop a cutting edge quality level in terms of porosities and inclusions

• Mirrors:

– Match fine microstructure with increased optical performance

– Develop large dimensions up to 1 mtr

• Moulds:

– Realise high quality optical mould surface without the use of a Ni-coating

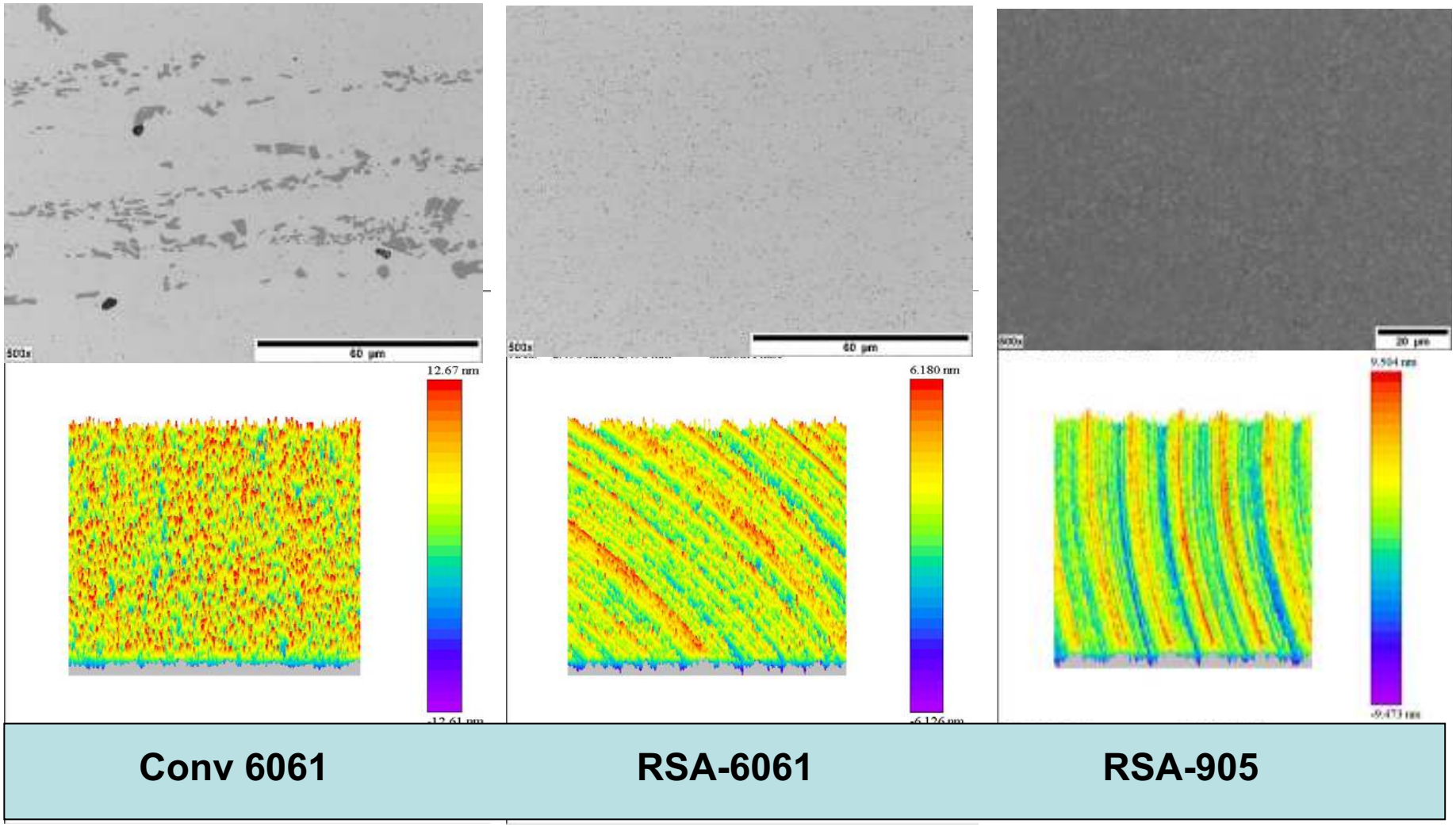
– Increase mechanical properties at elevated Temperatures

Actually developed and commercially available alloys for optical applications compared with conventional solutions:

Alloy	Physical properties					Mechanical properties 20 C			Typ. Compositions in %											
	Density	Youngs Modulus [Gpa]	Hardness [HB]	Thermal Cond. [W/m-k]	Thermal Exp. [µm/m°C]	UTS [Mpa]	YS [Mpa]	elong [%]	Si	Fe	Ni	Cu	Mg	Zn	Cr	Zr	Mo	Mn	Ti
RSA-6061	2,70	70	100	130	24	330	295	15	0,6	0,2	-	0,3	1,0	0,10	0,2	-	-	0,1	0,1
RSA-905	2,95	90	150	100	18	550	410	5	-	2,5	5,0	2,5	0,6	-	-	0,8	0,8	1,0	0,6
RSA-601	2,70	75	145	130	21	460	425	10	1,5	0,5	0,5	1,2	1,4	0,6	0,1	0,2	-	1,0	0,2
RSA-443	2,55	100	110	150	13	250	150	2	40	-	-	-	-	-	-	-	-	-	-
AA-6061	2,70	70	90	130	24	310	275	12	0,6	0,5	-	0,3	1,0	0,1	0,2	-	-	0,1	0,1
Ampcoloy-940	8,70	131	210	208	17,5	660	517	13	0,7	-	2,5	96,0	-	-	0,4	-	-	-	-

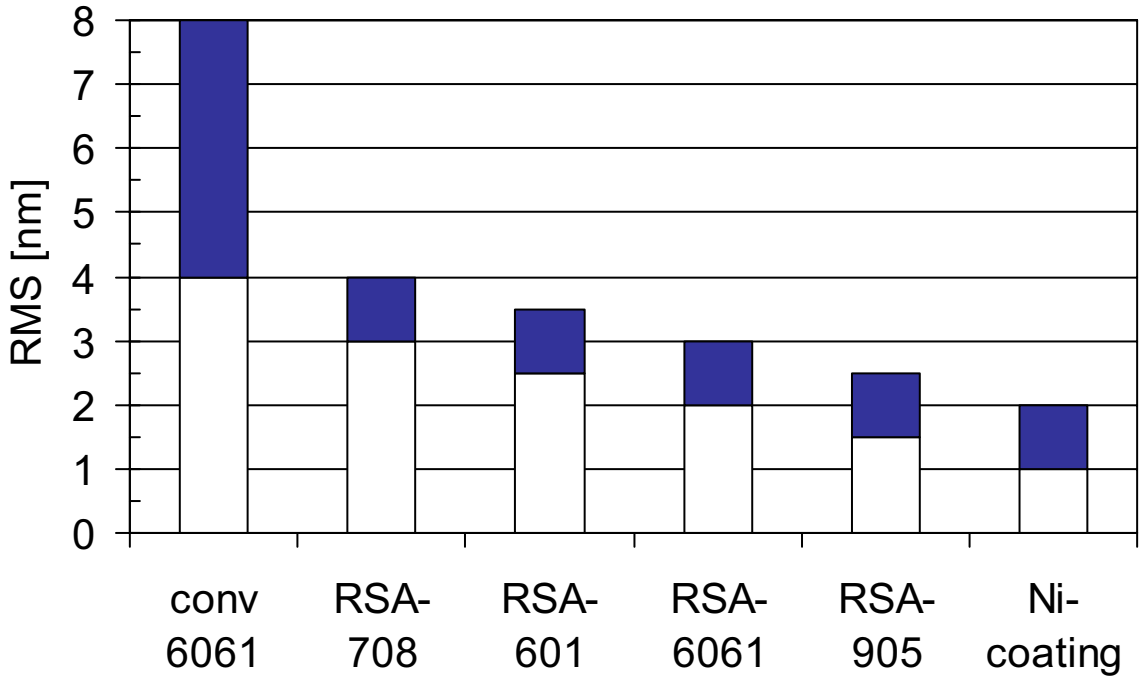
Experience in the market:

- Mirrors: results from about 75 customers
- Moulds: results from about 20 customers

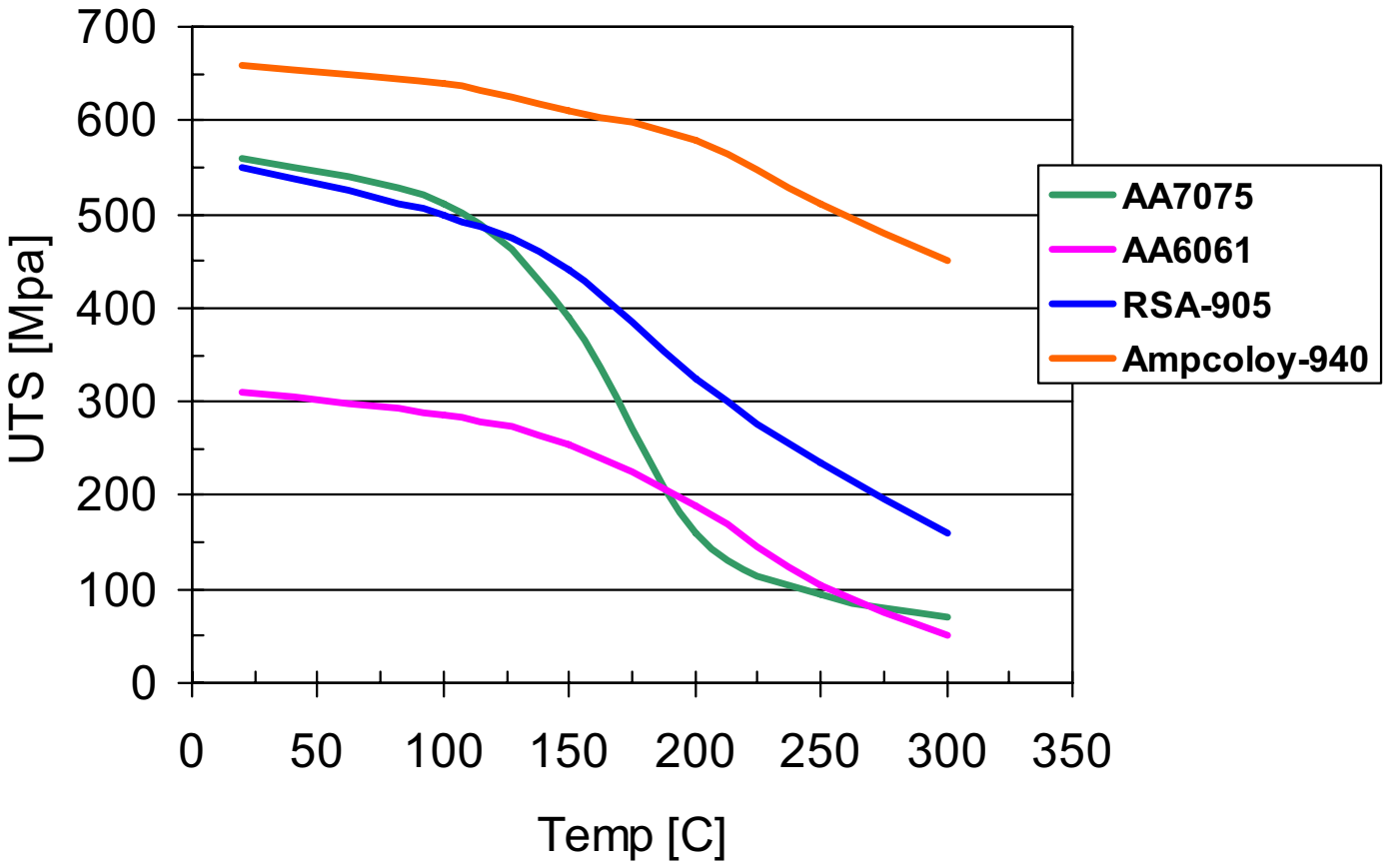


Conv 6061	RSA-6061	RSA-905

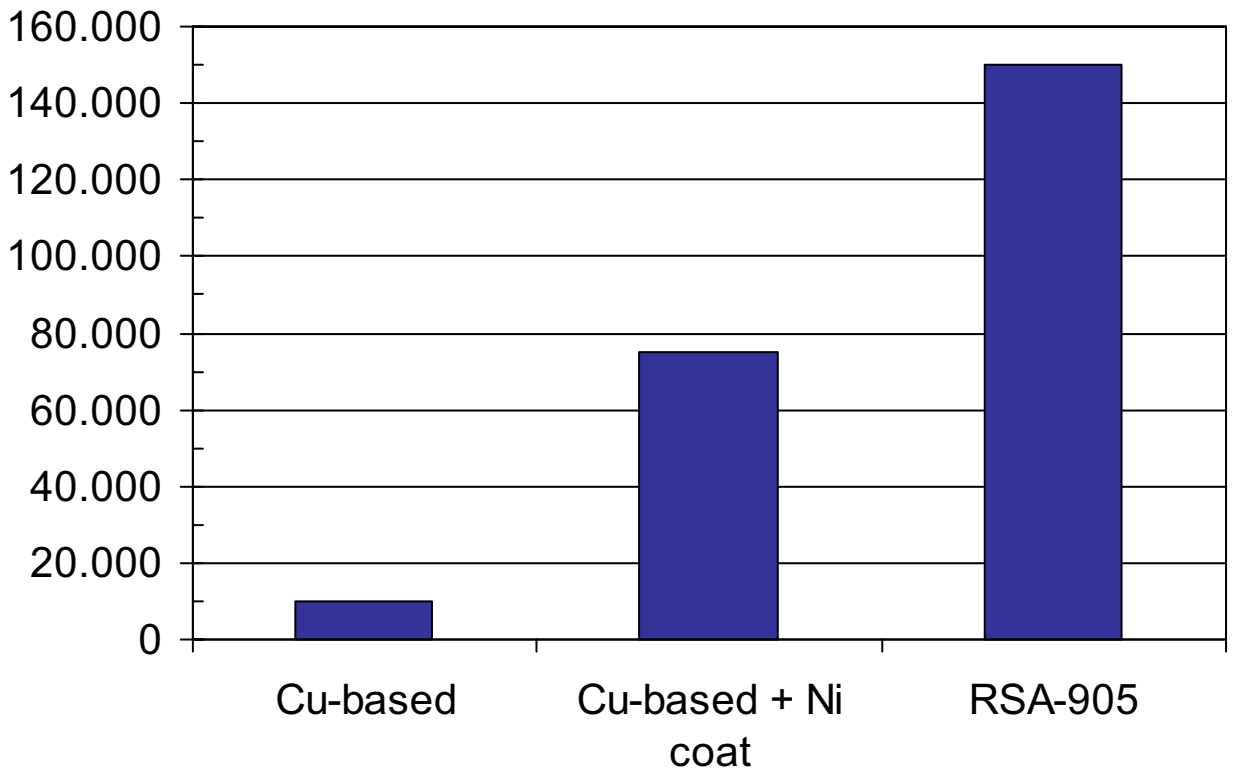
Typical RMS values after diamond machining of various alloys



Mechanical properties at elevated Temperatures of various alloys conventional and RSA



Typical mould life in number of shots as experienced by several different customers



Future developments RSA alloys for optical moulds:

Improve functionalities:

- Minimise surface roughness
- Optimise machinability
- Maximise mould life (1.000.000 shots achievable?)

Technical areas:

- Maximise Extrusion Ratio (Hydrostatic extrusion)
- Explore possibilities of polishing
- Explore possibilities of DLC coating

Case Zeiss

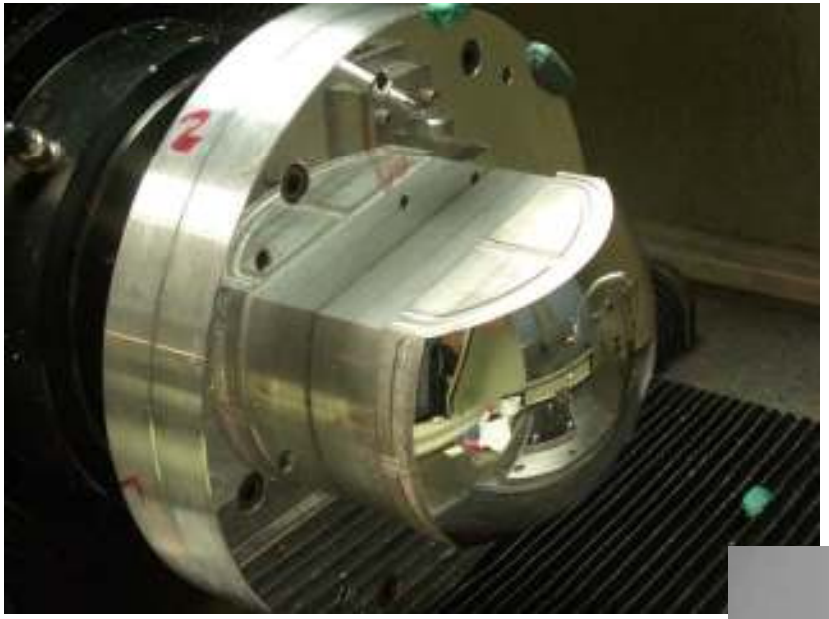
Source: Zeiss

- **Problem description:**
  - Conventional mould materials for optics require Ni-coating; moulds for niche applications have too long lead times (weeks – months) and are expensive due to many processing steps

- **Existing mould material solution:**
  - Steel / stainless steel with Ni-coating

- **Objectives:**
  - Evaluate RSA-905 as a short lead time mould technology
  - Realise short lead time by reducing production steps (days-weeks in stead of weeks-months)
  - Test in optical high demanding application: sunglasses

Source: Zeiss



Mould after diamond turning process

Sunglass design

Source: Zeiss

- **Results:**
  - Diamond machining of RSA-905 is easy
  - Polished surface is good enough but less brilliance than Ni-coating
  - Significant reduction of lead time is realised: roughly 60%
  - Significant reduction of mould cost is realised: roughly 30%
  - Up till now several-1.000 parts have been produced and still running
  - Moulded sunglasses are well within tolerances: optical as well as geometrical

Source: Zeiss

- **Conclusions:**
  - RSA-905 is a good option for a mould material in case of time critical solutions for prototype series and customised niche products
  - By replacing Ni-coated steel with uncoated RSA-905 a significant reduction in lead time (roughly 60%) and cost (roughly 30%) can be made

- **Future requirement:**
  - Improvement of surface robustness (scratch sensitivity) in order to improve resistance in daily production practice

Source: Zeiss

Case Jenoptik

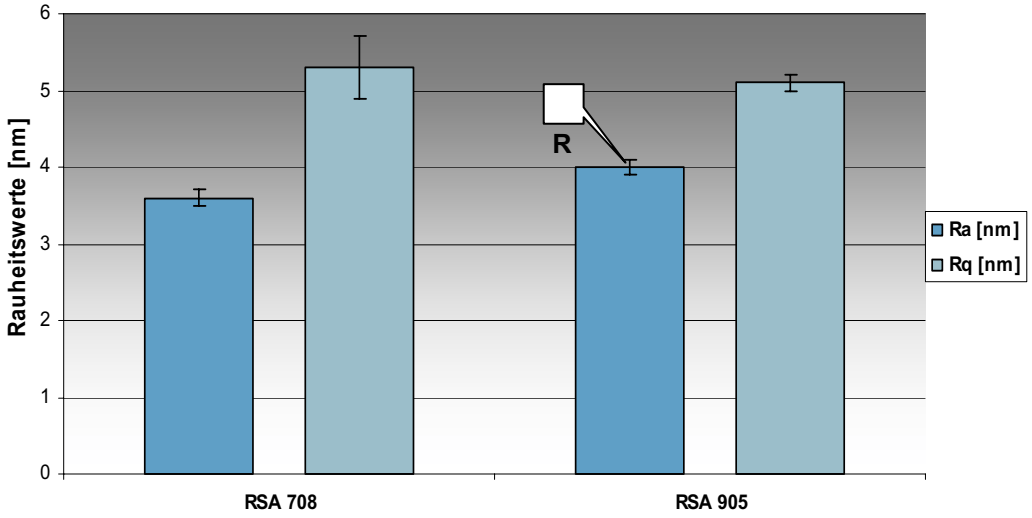
- **Problem description:**
  - Diamond tool wear on Cu-based solution (Ampcoloy) is too high for realising good surface finish and shape tolerances
  - Ni-coated Cu-based or steel solution has technical limitations, is logistically slow and expensive

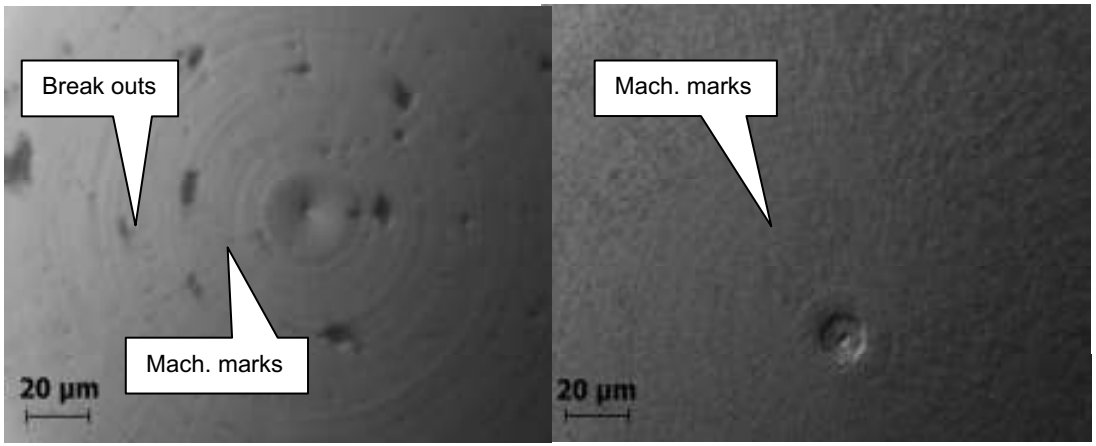
- **Existing mould material solution:**
  - Steel with Ni-coating for large series: several 1.000.000's
  - Ampcoloy-944 with Ni-coating for small series: up to several 1.000's

- **Objectives:**
  - Find a better solution for Ampcoloy regarding improved tool wear and better accuracy
  - Characterisation of RSA-708 and RSA-905 regarding diamond machining and mould practice

Source: Jenoptik

Surface finish after diamond turning / RSA-708 vs RSA-905

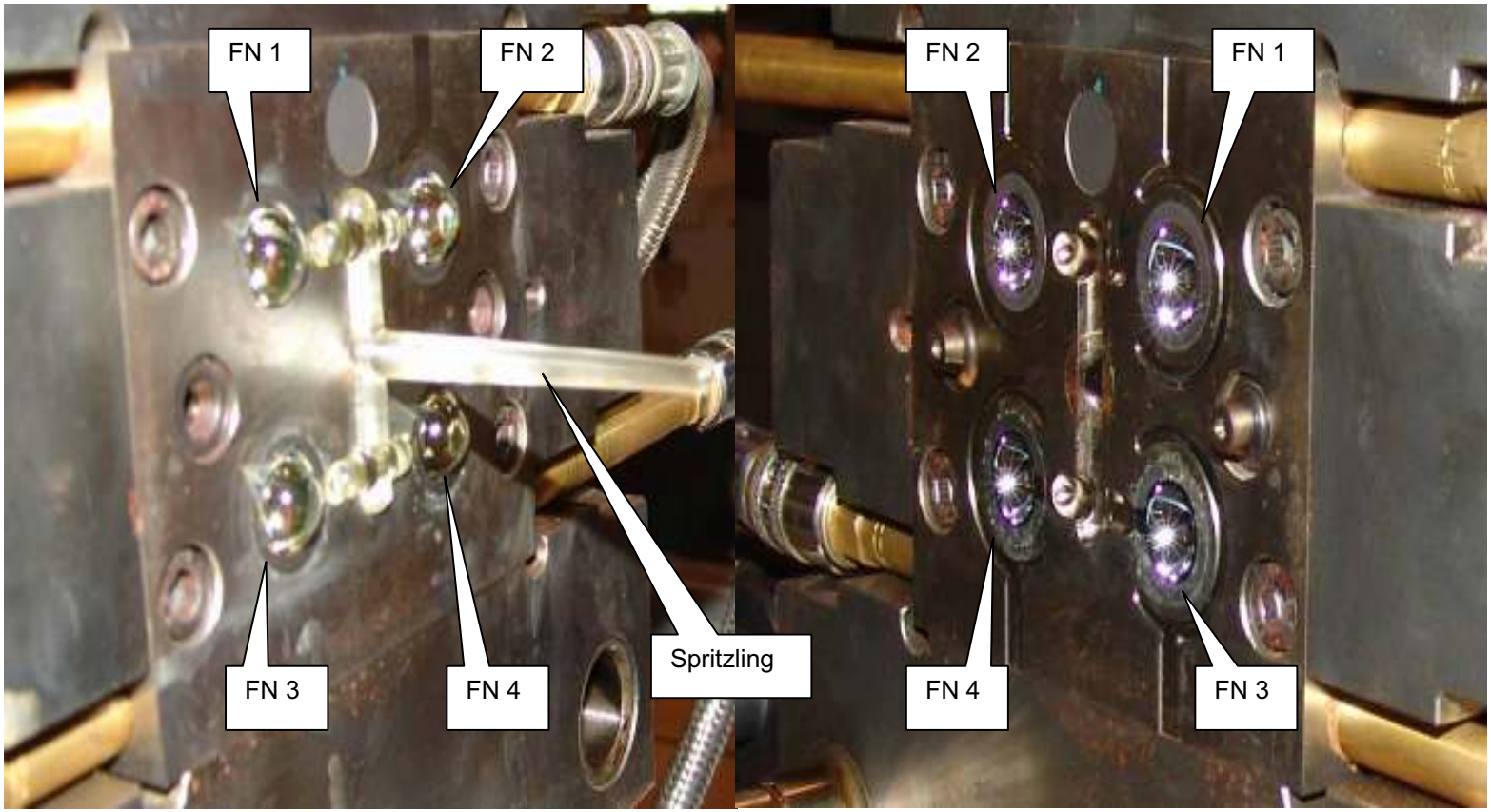




- Surface finish is considered ‘very good’
- Surface figures of both alloys are comparable
- RSA-905: smooth surface
- RSA-708: ‘break outs’

Source: Jenoptik

Mould configuration



In total 5.000 parts have been produced;
T(substrate)= 300C; T(mould)= 115C;
Injection pressure= 2.000bar; cycle time = 220sec

Source: Jenoptik

- **Conclusions:**
  - Machinability of RSA alloys is better than Ampcoloy: less tool wear, better surface finish and tolerances
  - RSA-905 performs better than RSA-708 due to better surface finish after machining as well as in mould practice
  - RSA-905 offers additional advantage compared to conventional solution due to absence of Ni-coating: better logistics and lower cost
  - RSA-905 is the superior alloy for injection moulding of optical parts and will be used as the standard solution for Jenoptik

- **Follow up:**
  - Evaluate performance RSA-905 in larger series (100.000 shots)
  - Characterise RSA-905 as moving insert (ejector)

Source: Jenoptik

Case Dr. Schmidt Intraocularlinsen

- **Problem description:**
  - Conventional tooling solution with Ni-coating costs an extensive amount of work
  - Practical limitations due to thin layer thickness: e.g. damaging diamond tool

- **Existing mould material solution:**
  - Steel with Ni-coating

Source: Dr. Schmidt

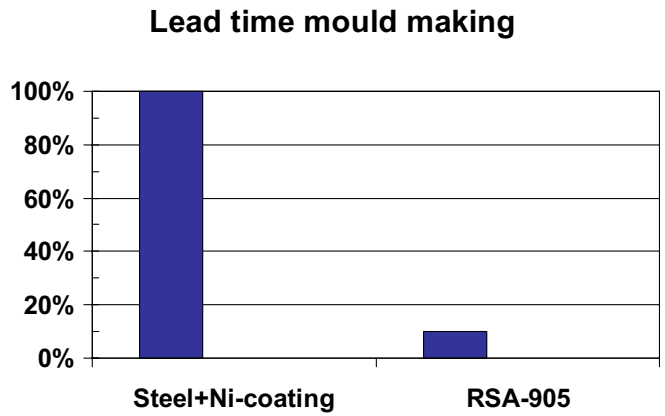
- **Objectives:**
  - Find a material with easier handling; simple logistics
  - Similar optical and production behaviour
    - Fine surface finish after diamond machining
    - Low thermal expansion
    - High thermal conductivity
    - Good mechanical properties at Temp

Source: Dr. Schmidt

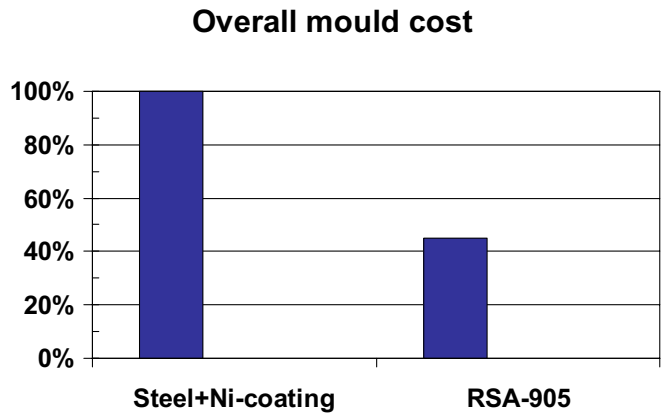
- **Results:**
  - Back to back comparison RSA-905 vs steel+Ni-coating
  - Machining parameters: comparable for both materials
  - Surface finish: both materials show very good surface finish
  - Injection moulding practice:
    - both materials show comparable behaviour
    - moulded lenses from both materials show high optical image quality
  - Up till now several-1.000 parts have been produced

Source: Dr. Schmidt

- **Results:**
  - Significant reduction in lead time: 90%.



  - Significant reduction in mould cost:
    - Material cost: reduction > 90%
    - Machining cost: reduction > 50%



Source: Dr. Schmidt

- **Conclusions:**
  - RSA-905 as un-coated mould material offers the opportunity for easy logistics and therefore saves time and manpower
  - RSA-905 is actually being used as the standard mould material for producing Intra-ocular lenses at Dr. Schmidt

- **Follow up:**
  - Be happy with a good, simple and cheap solution: RSA-905

Source: Dr. Schmidt

Case Fraunhofer IPT

- **Problem description:**
  - Optical structures tend to get more detailed; conventional material solutions (like Cu-based alloys) cannot support this tendency
  - Ni-coatings seem a good candidate but have limited use in practice: limited layer thickness and strong variations in quality

- **Existing material solution:**
  - Nickel coating (usually on steel, sometimes on Cu-based alloy)

- **Objectives:**
  - Find a better solution for Ni-coating by comparing different materials after micro structuring by diamond turning with mirror finish
  - Optimise machining parameters in order to get optimised results: good optical surface quality, good form accuracy, free of burr

Source: Fraunhofer Institut Produktionstechnologie

Experiment setup

Machining:

Machine: Precitech Nanoform® 350

Work piece: Diameter: 30mm

Process: Plunge Cutting

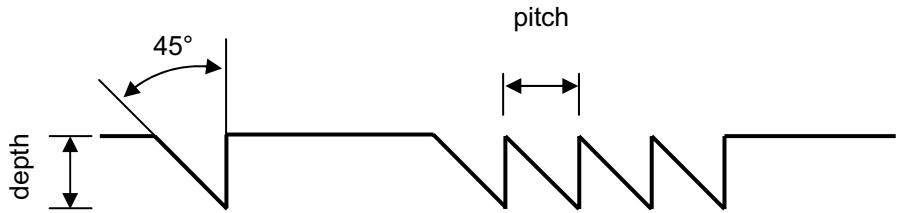
Structure:

Single groove

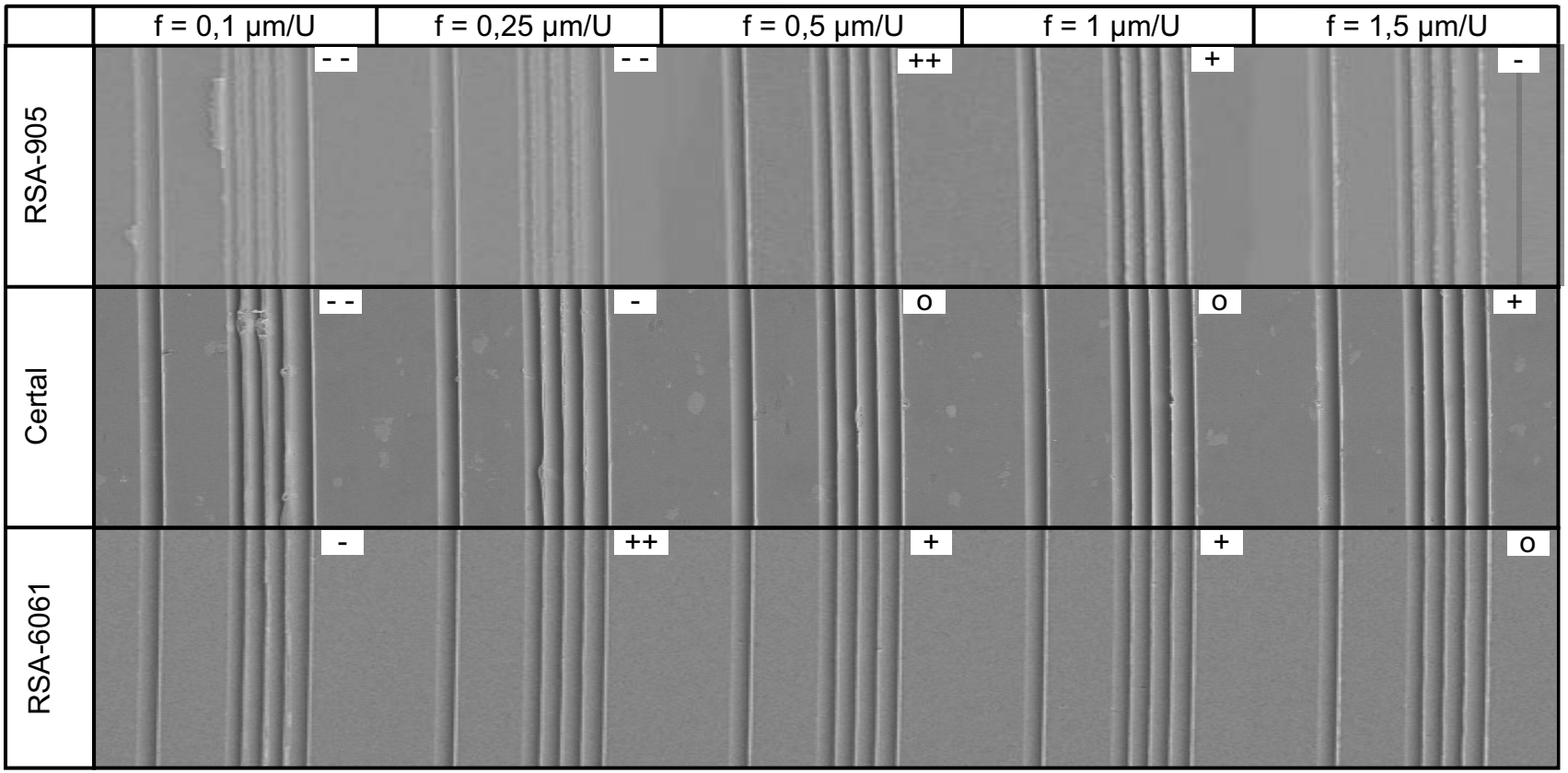
Array of four grooves

Structure angle: 45°

Depth = pitch < 10 µm



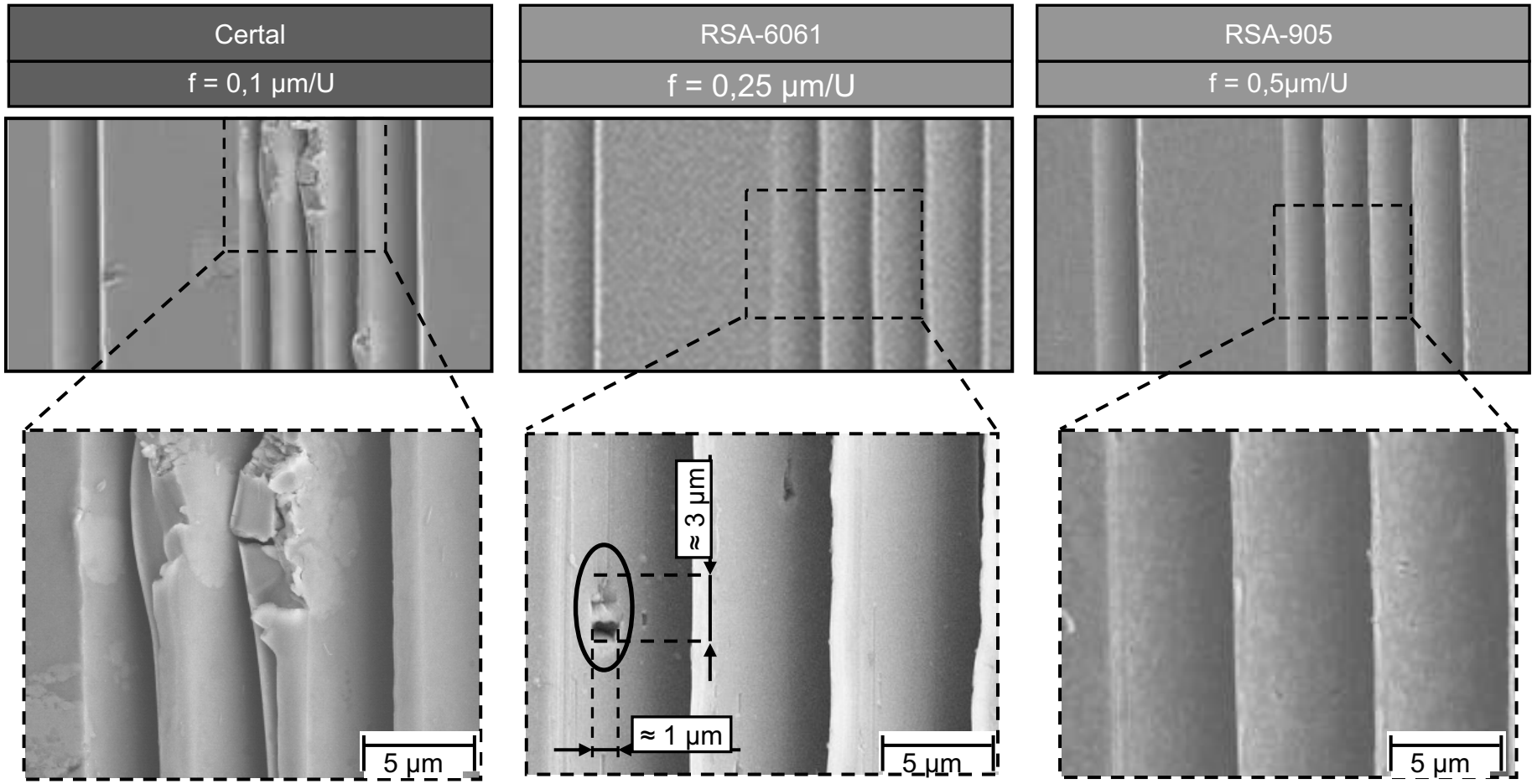
Source: Fraunhofer Institut Produktionstechnologie



Best parameters:

- RSA-6061 f= 0,25 µm/rev
- RSA-905 f= 0,5 µm/rev

Source: Fraunhofer IPT Institut Produktionstechnologie



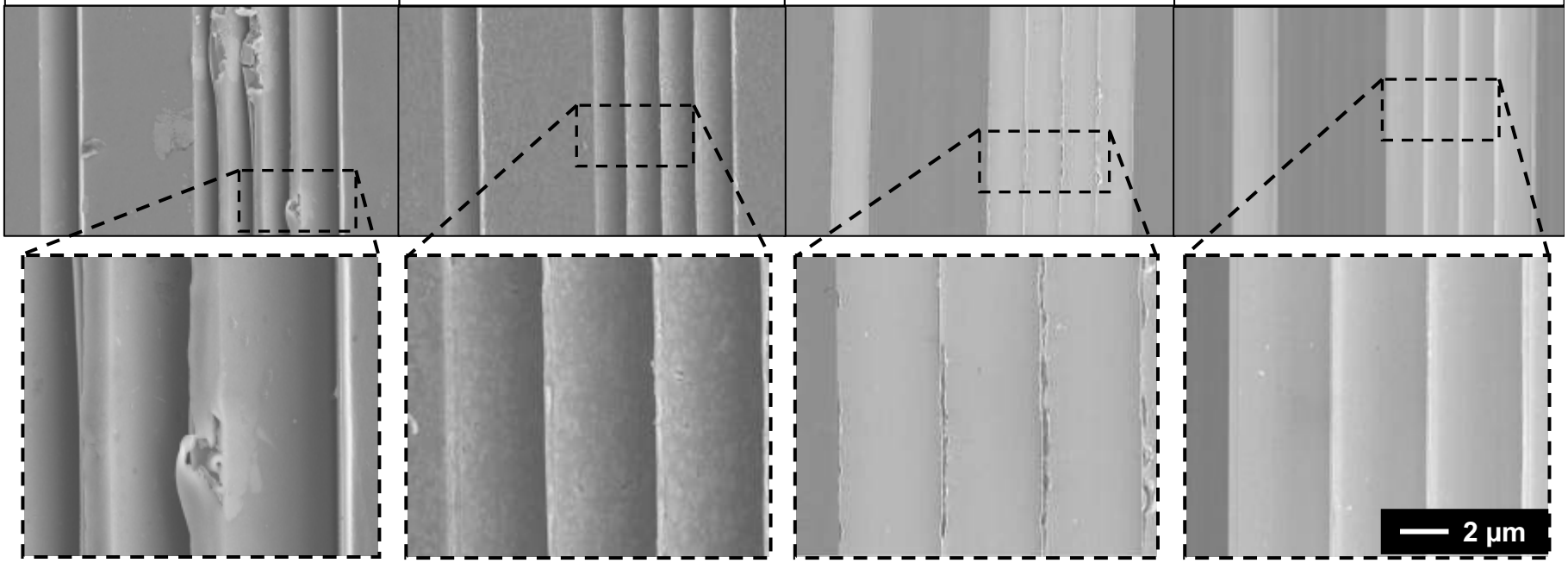
Remarkable results:

- Conv 7022 (Certal): Lots of large ‘break outs’
- RSA-905 shows strong deformations when f< 0,5 µm/rev

Source: Fraunhofer Institut Produktionstechnologie

Comparison between aluminium and Ni-coating

Aluminum		Nickel-Phosphorous Coating (NiP)	
Certal	RSA-905	Galvanic	Electroless
f = 0,1	f = 0,5	f = 0,5	f = 0,25



Source: Fraunhofer Institut Produktionstechnologie

- **Conclusions:**
  - Electroless Ni-coating shows best results: good surface quality and good shape accuracy; but has limited practical use
  - RSA-905 shows good quality, no particle break outs, SEM picture shows small surface irregularities
  - RSA-6061 shows reasonable results; small grain size and particles, but hard particles can break out and hurt the surface by scratching
  - Conv 7022 (Certal) show poor results due to braking out of large particles (presumed Si and Mg)

- **Follow up:**
  - The good results of RSA-905 are a basis for further investigations: further analysis and optimisation of machining parameters, tool setup, tool wear, ….