LIVING GLASS SURFACES 2023

CONSIDERATION OF SENSORY APPROACHES FOR THE SUSTAINABLE MANUFACTURE OF OPTICAL COMPONENTS

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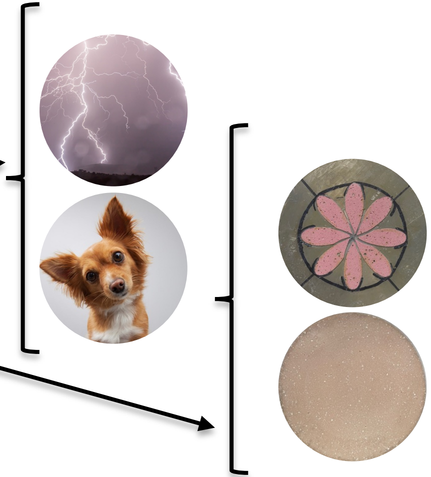
Agenda

1. Glass Polishing
2. Measurements - sensors
3. Experimental setup
4. Experimental results
5. Conclusion
6. Outlook

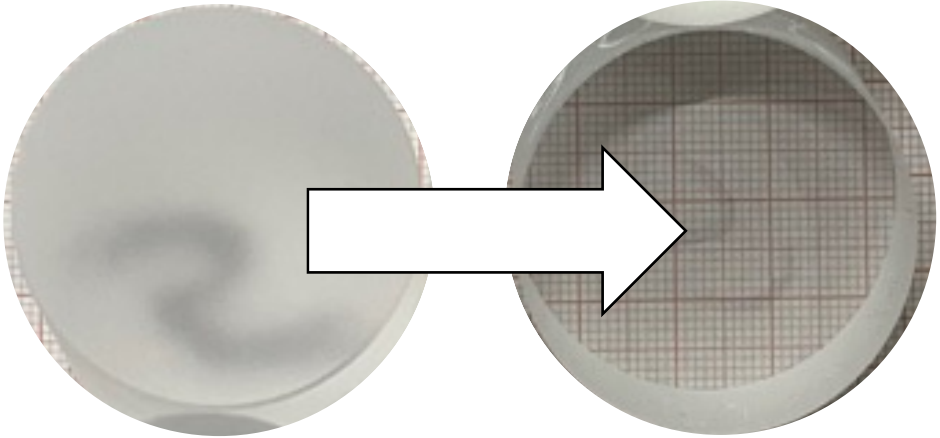


Agenda

GLASS POLISHING

OVERVIEW

- Chemical and mechanical interactions
- Several process variants: **synchrospeed**, overarm polishing, CNC polishing
- Dependent on various process parameters (glass type, pressure, pH-value of the slurry, slurry grain size, …)
- Four process partners: glass, machine, polishing carrier, polishing slurry
- Standard slurry: based on CeO_2



Polishing process – an opaque surface gets smooth and transparent. The state of the opaque surface is the starting point for most experiments and is generated by a grinding process. The diameter of the samples is 40 mm.

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MEASUREMENT - SENSORS

POWER MEASUREMENT

- Electrical power: energy converted in a defined period of time, current value $p = v\,i$
- Active power: $P = \bar{p} = {}^{1}/_{T} \int_{T}^{t_0+T} v\,i\,dt$
- Measurement of the active power every 250 ms
- Representative for mechanical power during process (friction, pressure, speed, …)
- Apparent power (VA, 3), active power (W, 2) and reactive power (VAr, 1)

Switch cabinet of the polishing machine Stock RSP 40 with integrated power sensors.

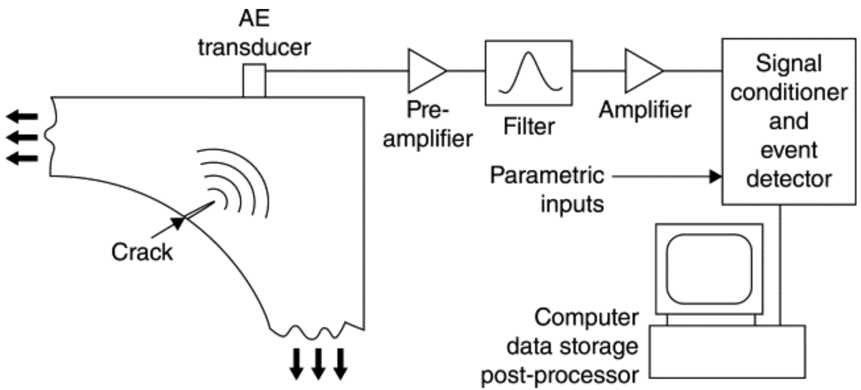
Relation between reactive power (1), active power (2) and apparent power (3).
Source Picture: http://profi-stromgenerator.de/tag/scheinleistung/, 01/09/23

- v: voltage
- i: current

MEASUREMENT - SENSORS

ACOUSTIC EMISSIONS (AE)

- Transient waves in a material, generated by the sudden release of energy (elastically stored)
- Other sources: processes involving friction and rubbing, leakage of fluids
- Signals in the ultrasonic range (> 20 kHz - approx MHz)
- Signal acquisition: piezo microphones
- (Direct) contact between sensor and process is not necessary!



Signal acquisition and conditioning of acoustic emissions (https://www.sciencedirect.com/topics/chemistry/acoustic-emission, 11/04/23)

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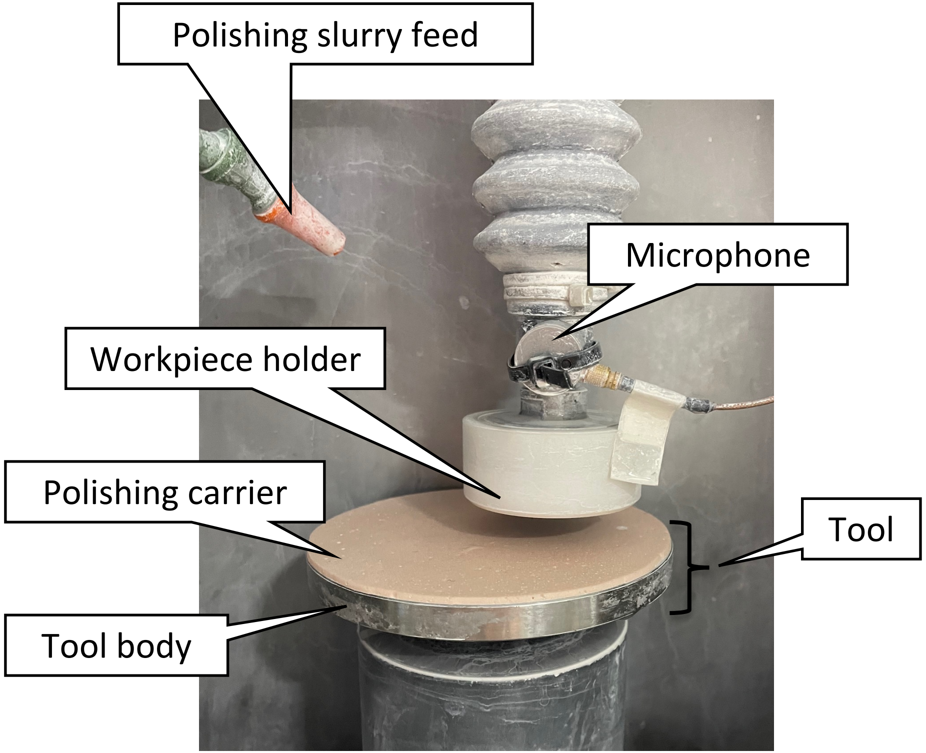
EXPERIMENTAL SETUP

DATA ACQUISITION

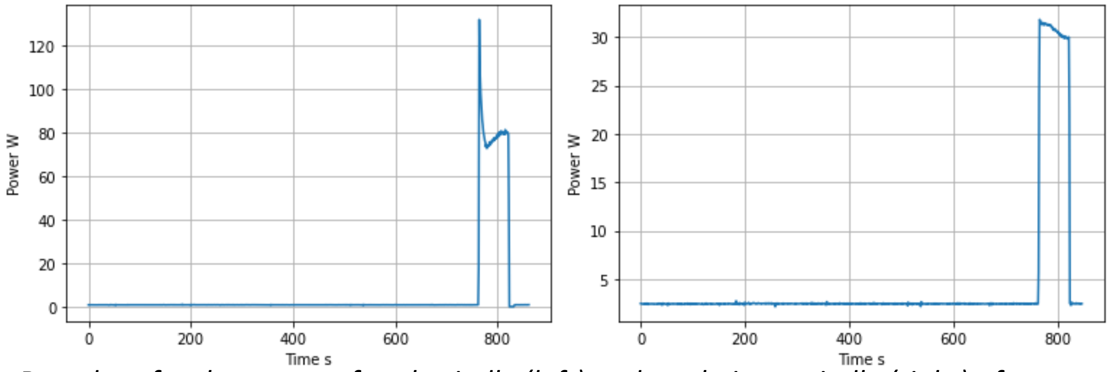
- Integration of the microphone in the machining room
- Live measurement of acoustic emissions during process
- Sampling rate: MHz range -> huge amount of data (approx. GB/min)
- Microphone: waterproof, but: holding is necessary, either cable ties (picture) or special holder (additive manufactured)
- Cables need protection



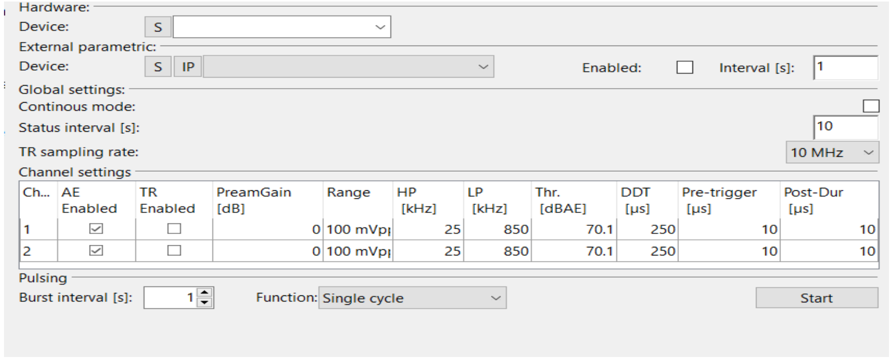
Look in the machining room of a conventional polishing machine with integrated polishing sensor.

EXPERIMENTAL SETUP
DATA PROCESSING

- Main problem: complicated course of the polishing process
- Signal smoothing is necessary
- Size of polishing gap can cause signal offsets
- AE data in the range of GB -> simplification, mean values, removal of noise levels is necessary



Raw data for the power of tool spindle (left) and workpiece spindle (right) of a polishing process. The high peak at the beginning (tool spindle) is caused by the high starting current of a motor.



Screenshot of the data acquisition windows – the sampling rate is set to 10 MHz.

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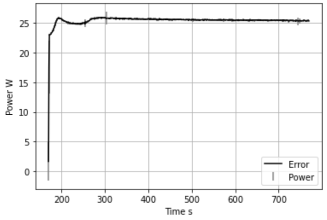
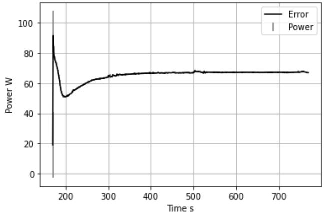
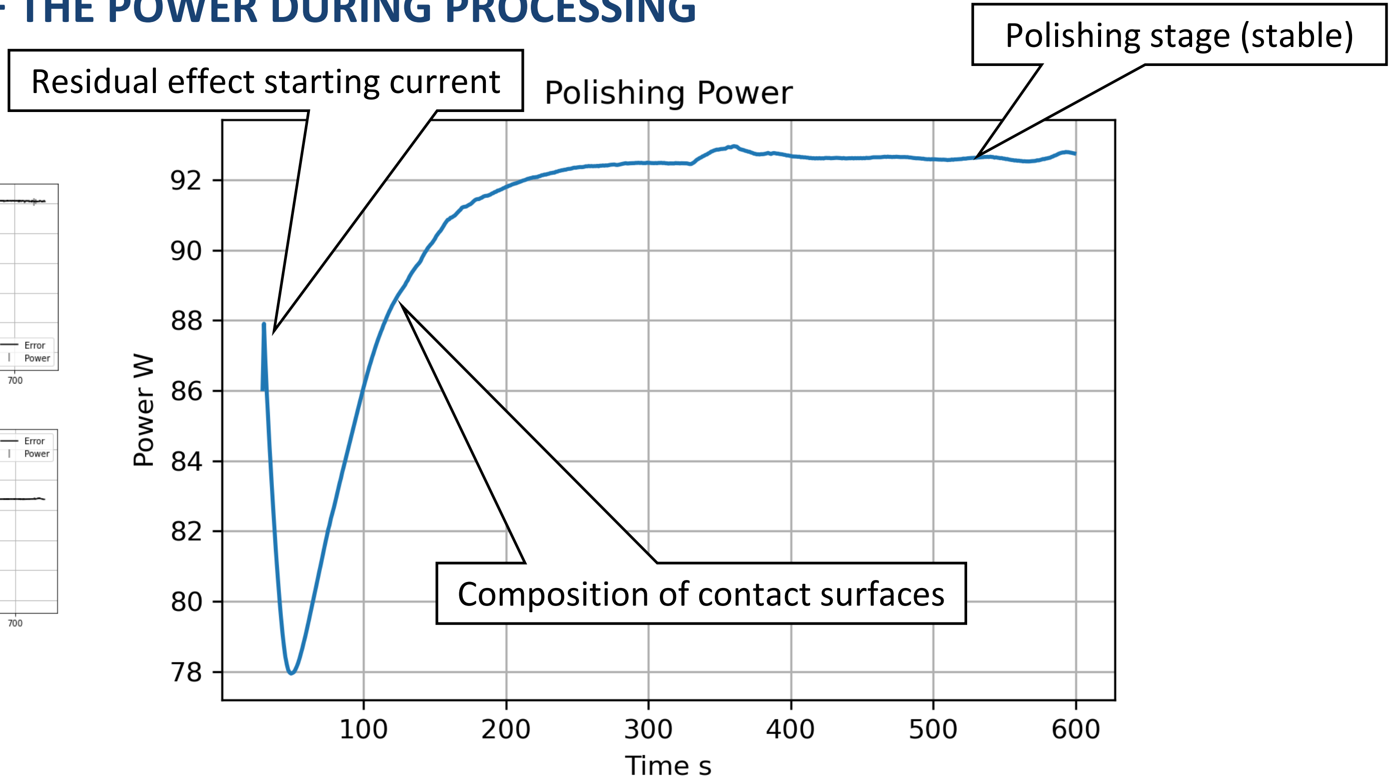
EXPERIMENTAL RESULTS

COURSE OF THE POWER DURING PROCESSING

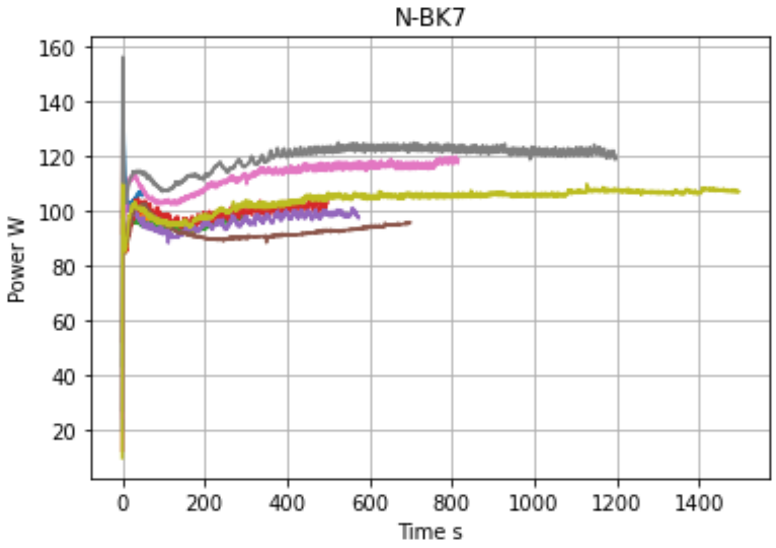


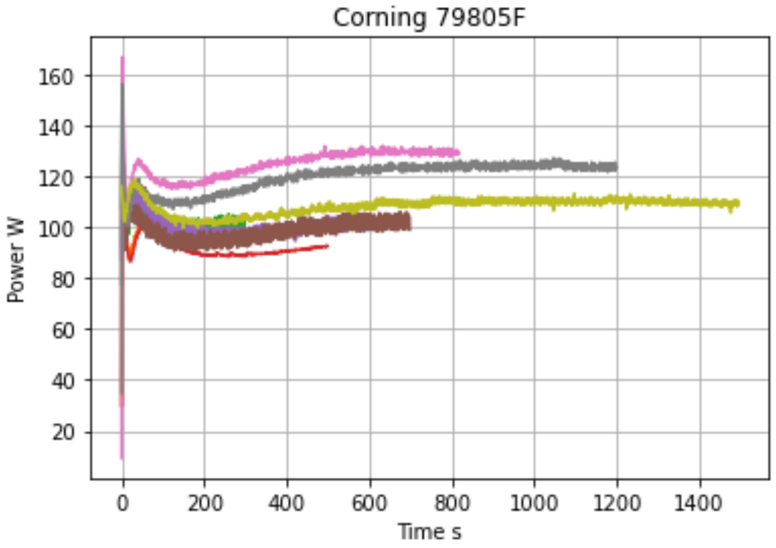




EXPERIMENTAL RESULTS

POLISHING EXPERIMENTS – TIME COURSE FOR DIFFERENT GLASSES

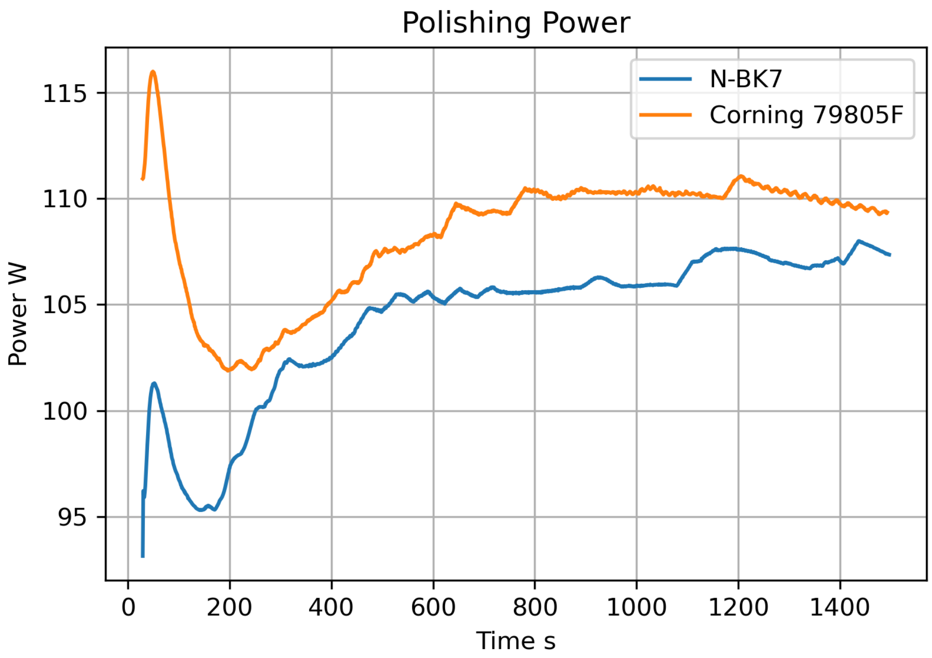




- Offset between experiments: polishing gap
- Composition contact surfaces for all experiments

EXPERIMENTAL RESULTS

LONG TIME POLISHING EXPERIMENTS



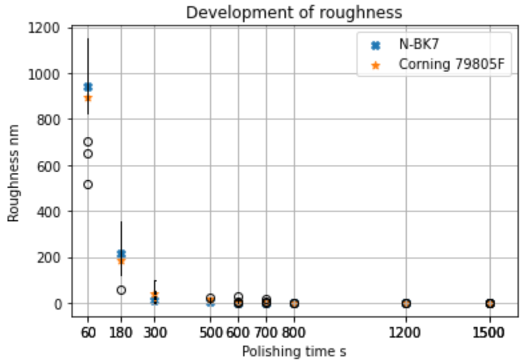
- Stable state after approx. 600…800 sec.
- Between 1000 and 1200 sec: rise of energy
- Experimental data suggest different hardness for long time experiments
- Different time until static process: allegedly chemical different behaviour of glass

	N-BK7	Corning 79805F
Final roughness [nm]	0,271	0,227
MRR [mm^3/min]	4,09	2,12

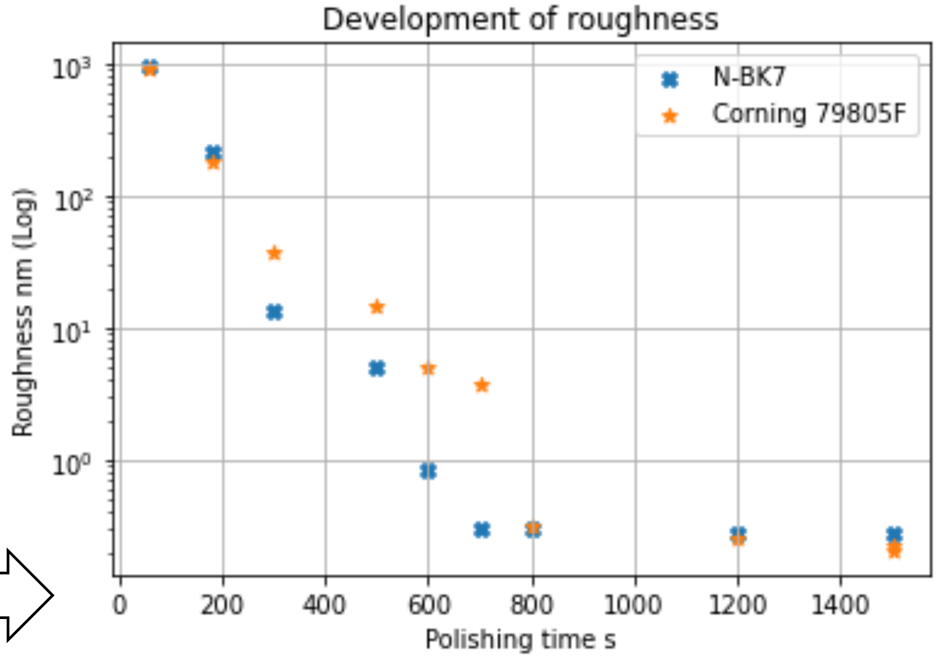
Material **R**emoval **R**ate

EXPERIMENTAL RESULTS

ROUGHNESS BEHAVIOR



Roughness values in linear scale: only the first seconds are visible!



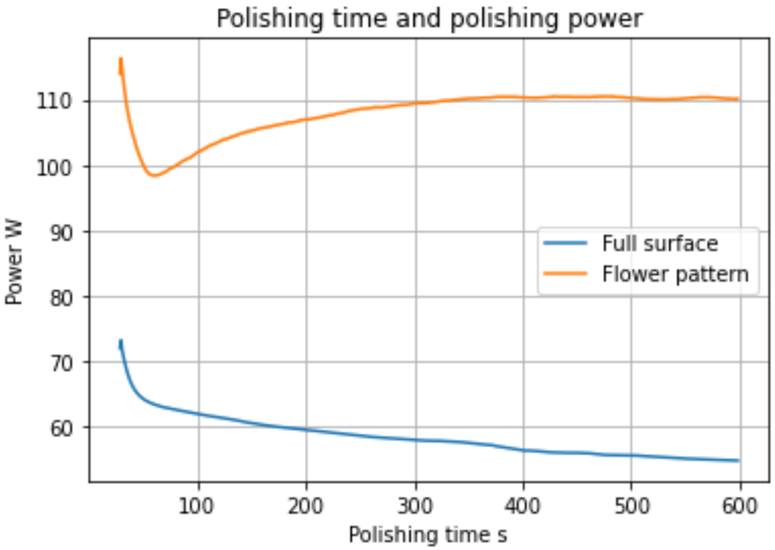
Roughness values in logarithmic scale – at about 600…800 seconds the roughness values are constant and lower than 1 nm.

EXPERIMENTAL RESULTS

VARIATION OF THE POLISHING CARRIER PATTERN (FLOWER PATTERN)

- Flower pattern – higher MRR and better roughness
- Better slurry transport
- Less smearing of the polishing carrier.

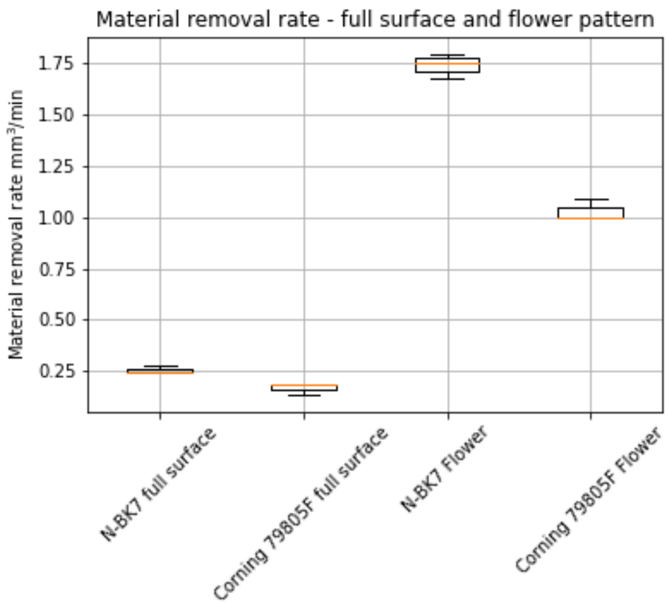
Flower pattern polishing pad

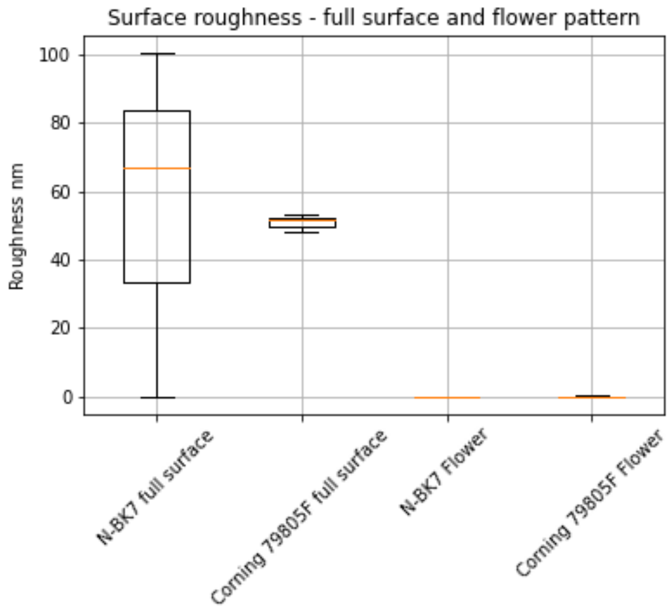


Values of the polishing power for a 600 seconds polishing time experiment. The power is higher for flower pattern polishing carriers.

EXPERIMENTAL RESULTS

FLOWER PATTERN – ROUGHNESS AND MATERIAL REMOVAL



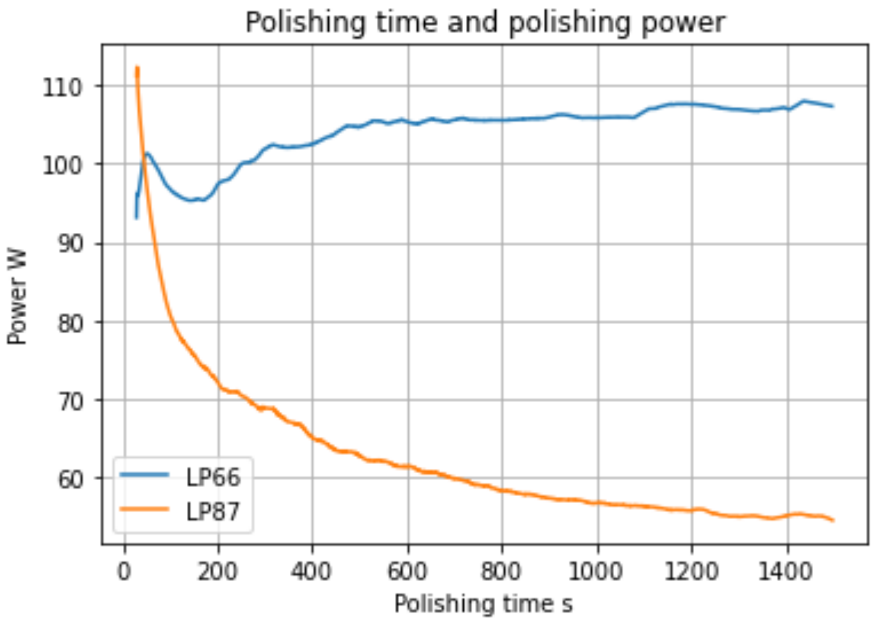


Material removal rate and roughness for glass samples with full surface and flower pattern. The values for material removal rate and roughness get better with the flower pattern polishing carrier.

EXPERIMENTAL RESULTS

VARIATION OF THE POLISHING CARRIER TYPE

- LP66/ LP66
- Long time experiments (1500 sec)
- Hardness LP66: 25 (Durometer D)
- Hardness LP87: 47 (Durometer D)

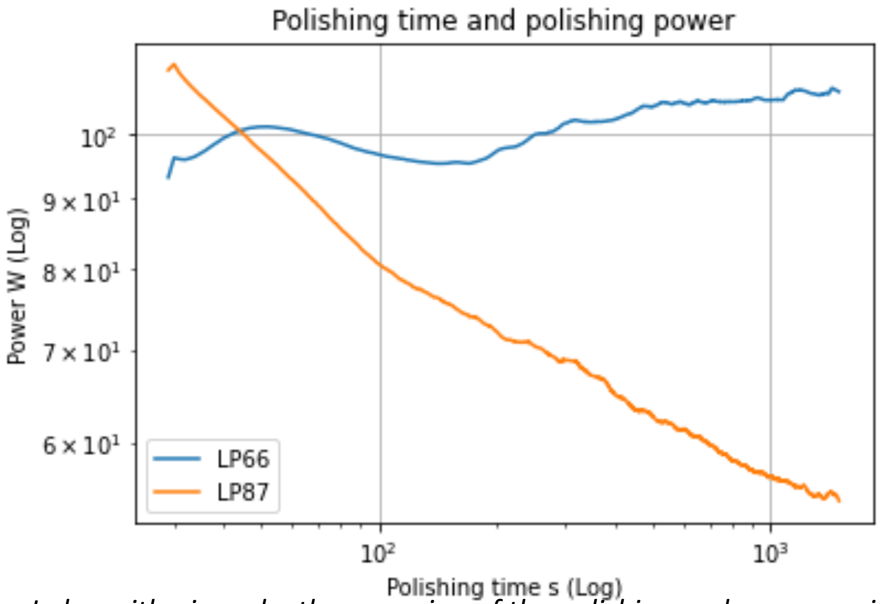


Different polishing carrier types
Source Picture: https://pieplow-brandt.de/wp-content/uploads/2019/06/LP_list.png, 04/09/23

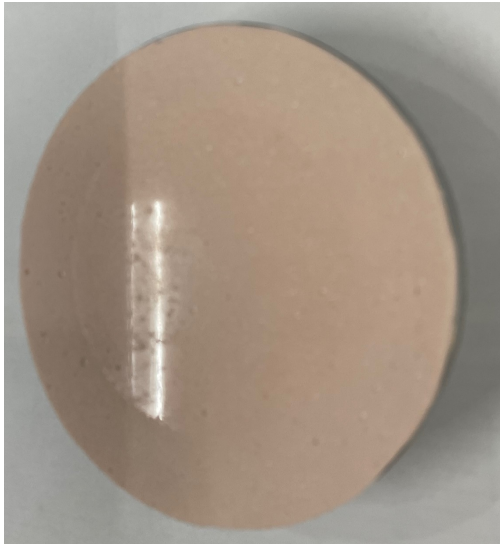
N-BK7	LP66	LP87
Final roughness [nm]	0,271	2,453
MRR [mm^3/min]	4,09	0,83

EXPERIMENTAL RESULTS

VARIATION OF THE POLISHING CARRIER TYPE – LOGARITHMIC SCALE



In logarithmic scale, the smearing of the polishing pad expresses itself in the form of a falling straight line over a greater range. However, the power consumption of the non-smeared pad is more or less constant.

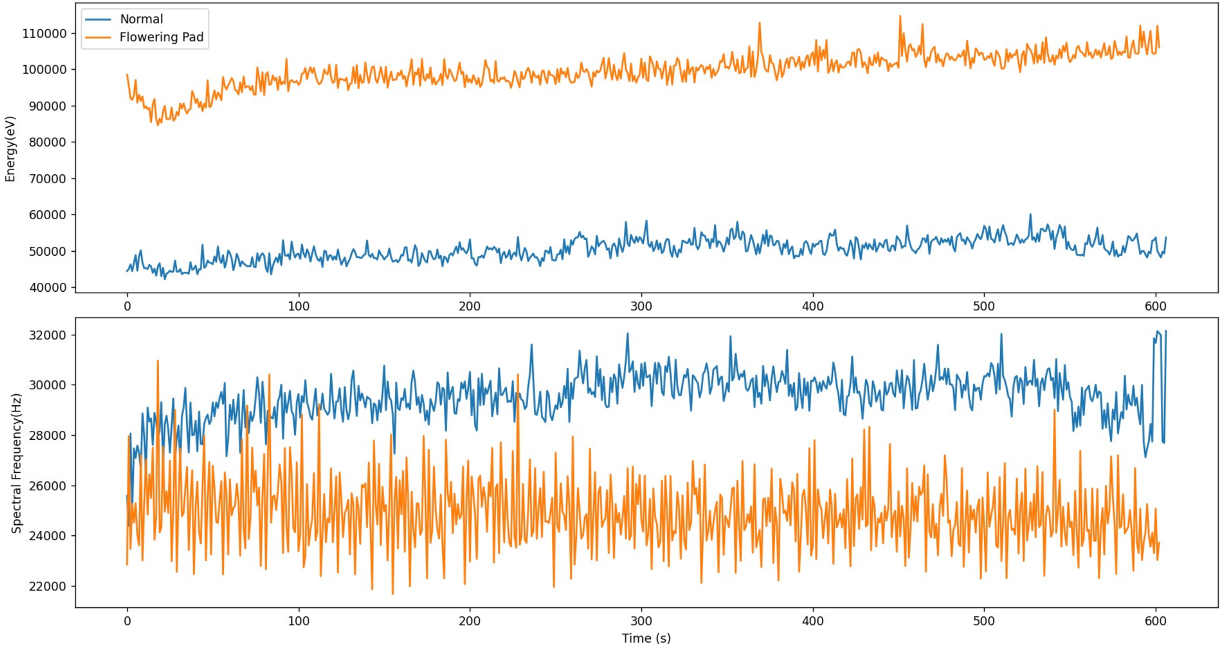


Smeared polishing pad – the surface is smooth and reflects the light.

EXPERIMENTAL RESULTS

ACOUSTIC EMISSIONS – GENERAL COURSE OF A POLISHING PROCESS FOR FULL SURFACE PAD AND FLOWER PAD

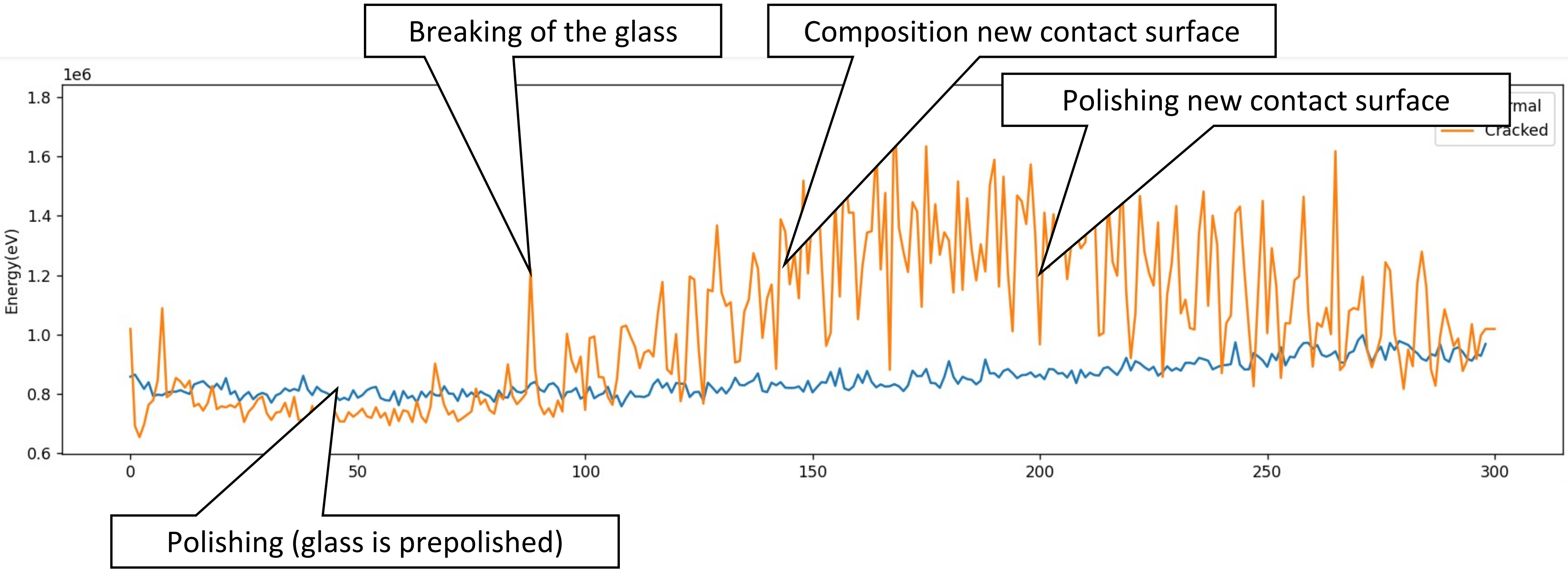
- Identical parameters
- Trend: non flower pad seems to smear – i. e. MRR and roughness get worse.



Corning 79805F	Full	Flower
Final roughness [nm]	108	0,842
MRR [mm^3/min]	0,136	1,36

EXPERIMENTAL RESULTS

ACOUSTIC EMISSIONS – CRACKING OF THE GLASS



Agenda

CONCLUSION

- Sensors can help to detect wether a process is finished (**end-point-detection**)
- It can help to see, wether the pad needs conditioning
- They can help to adjust the settings of the machine
- It is possible to recognize a cracking during polishing
- Sudden change of the acoustic energy in the process → something happened during processing
- **In general:** sensors can help to save energy and make a process at very different factors within the glass polishing process.

Source picture: pixabay

Agenda

OUTLOOK

- Integration and coupling of further sensors (flow sensors, chemical sensors)
- Live measurement of heat development during process
- Surface measurements: coupling of surface values and live measurements
- Further investigation of hardness during processing
- Model process interactions and live values

Source picture: pixabay

THANK YOU FOR YOUR ATTENTION!

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Backup: New Agenda