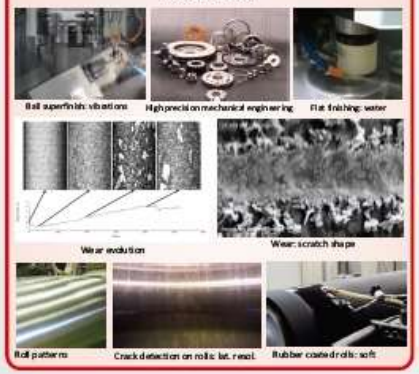
JRP-i15 Multifunctional ultrafast micro-probes for on-the-machine measurements

EMPIR EURAMET

EURAMET

Industrial need



State-of-the-art

- Convent. large tactile probes
- Optical line scan cameras (180 points, 1.3 mm, 2 kHz)
- Fast small areal AFM (5.6 mm/s, z < 10 µm)
- Piezoresistive Si micro-probes (15 mm/s)
  - noise: 40 pm/sqrt(Hz)
  - z-range: 70 µm
  - no damping: Q= 500
  - wear: 1.000 roughness meas. @ Ra < 2 µm

Challenges

- High measurement speed up to 15 mm/s
- Strong vibrations of workpieces
- Contamination of surfaces
- Temperature variations
- Wear of µP Silicon tips
- Simultaneous measurement of mechanical parameters
- Industry 4.0 requirements
- Digital transformation

Progress

- New micro-probes with diamond tips, critical damping, extended measurement range ± 200 µm, integrated actuator and preamplifier on the PCB
- Roughness probe with integrated feed-unit 15 mm/s
- High-speed functionality: contact resonance (CR) modulus mapping with new integrated actuators
- Test samples to verify instrumental properties
- Good Practice Guides (tip shape, layer thickness, wear volume, CR, FDC)

Impact


Paper industry


Medical industry


Transportation industry

Wear and friction reduction

WP 5 Creating impact

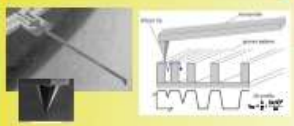
NPL, all partners (31 PM)

WP 1 Optimization of probing tips

BAM, BRT, CMI, GET, NA, NPL, PTB, RRI, TT, TUBS, VTT (53 PM)

Aim

To provide micro-probes with optimized tips and determine tip form and residual wear

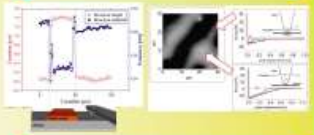


WP 3 Development of surface property measurement methods

BAM, CMI, NA, NPL, PT, RRI, TT, TUBS (52 PM)

Aim

To develop two different techniques: contact resonance (CR) and force-distance curve (FDC)

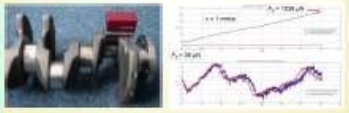


WP 2 Development of new micro-probes for industrial measurement conditions

BAM, GET, NA, PTB, RRI, TUBS, VTT (32 PM)

Aim

To develop new large deflection, low tip-wear micro-probes for simultaneous high-speed topography and elastic modulus measurements



WP 4 Development of measuring methods resistant against environmental influences

BRT, NPL, PT, PTB, RRI, TT, TUBS, VTT (49 PM)

Aim

To bring micro-probes on micro-finishing machines, paper and steel roll measuring machines and wear testers

Case Studies

1. Commercialization with TE 77
2. Integration of µP into AFM in SEM
3. CR in an SEM-AFM
4. Integration of µP into tribometer
5. Integration of µP into AFM SEM TM
6. Wear test with different tips

Knowledge Transfer

1. Creation of stakeholder group
2. Publications & web-pages
3. Good Practice Guides
4. Input for standardization bodies ISO/VAMAS/BSI/DIN/VDI
5. Press releases

Training and Dissemination

1. Training courses How to Use
2. Online training guides for end users
3. In-house demonstration & training
4. Exchange of staff
5. Industrial visits

Uptake and Exploitation

1. Develop exploitation plans
2. Make micro-profiler with integrated µP and feed-unit commercially available
3. Validated design for surface measurements for rolls
4. CMC entry for roughness measurements on µ-form elements with micro-probes

WP 6 Management *PTB, all partners (17 PM)*

Consortium

VTT MIKES METROLOGY · CMI CZECH METROLOGY INSTITUTE · nano analytik · BAM · THIELENHAUS TECHNOLOGY · RollResearch · NPL · PTB · breitmeier · PHOENIX TRIBOLOGY

Excellence

Internationally acknowledged experts, active collaborators
Outstanding and complementing metrology capabilities:

1. Leading expertise in the fabrication/metrology of piezoresistive silicon micro-probes (PTB, TUBS)
2. Leading expertise in numerical modeling and open source software (CMI)
3. Leading expertise in AFM force-distance curve metrology (BAM)
4. Leading expertise in high-speed metrology (BRT, GET, NA)
4. Long-term experience in the development of dimensional and material reference standards (BAM, BRT, NPL, PTB, VTT)
5. Int. activities in standardization committees (BAM, CMI, NPL, PTB, VTT)

Collaborators

Adama · Valmet · HILTI · EPMA · SANDVIK Coromant · µS

Workshop on multifunctional ultrafast microprobes for on-the-machine measurements

3rd June 2019
19th EUSPEN Conference, Bilbao

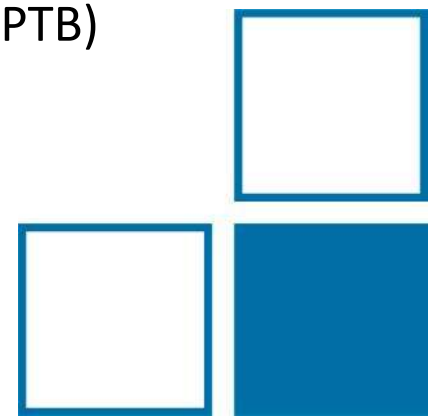
Traceable measurements of surface form and property are essential for controlling the use of or assessing the condition of machined parts and tools in high precision mechanical manufacturing machines especially when these components are subject to wear and surface contamination. Therefore, this project will develop new tactile microprobes for reliable and ultrafast, on-the-machine (i.e. in-line) topographical micro-form and roughness measurements that are 30 times faster than conventional methods and fast methods using contact resonance and force-distance curves to measure adhesion, stiffness, friction, coating thickness and to detect contaminants through adhesion contrast.

15:00	**Welcome** Uwe Brand, Coordinator of EMPIR project 17IND05 MicroProbes (PTB Braunschweig, Germany)
15:05	**Overview EMPIR project "17IND05 MicroProbes"** Uwe Brand (PTB Braunschweig, Germany)
	Fast piezoresistive silicon microprobes
15:15	**Future piezoresistive silicon microprobes for fast roughness measurements with high damping** Michael Fahrbach (TU Braunschweig/LENA, Germany)
15:35	**Tip flight and wear for fast roughness measurements** Heinrich Behle (PTB, Germany)
15:55	**Force distance curve (FDC) and contact resonance (CR) measurement modes for mechanical property measurements** Sebastian Backes (BAM, Germany)
16:15	**Compact microprobes with integrated traverse unit for fast roughness measurements** Michael Drexel (Breitmeier Messtechnik GmbH, Germany)
16:35	*Coffee break*
	In-line applications
16:50	**Measurement of micro-form and roughness on finishing machines** Sebastian Goeke (Thielenhaus Technologies, Germany)
17:10	**Application of fast silicon microprobes on roll finishing machines** Tuomas Lindstedt (Roll Research International, Finland)
17:30	**In situ Topography Measurement in Tribological Contacts** Timothy Kamps (NPL)
17:50	**Discussion of project aims and opportunities**
18:00	End of workshop
19:00	**Welcome reception** at San Mames football stadium
21:00	**End of first EUSPEN day**

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Overview EMPIR project “17IND05 MicroProbes” Multifunctional ultrafast microprobes for on - the - machine measurements

Uwe Brand
Project coordinator
Department 5.1 Surface Metrology
Physikalisch-Technische Bundesanstalt Braunschweig and Berlin (PTB)
Bundesallee 100, 38116 Braunschweig (Germany)



Overview

1. What are EMPIR projects
2. Motivation for the project
3. Objectives and partners

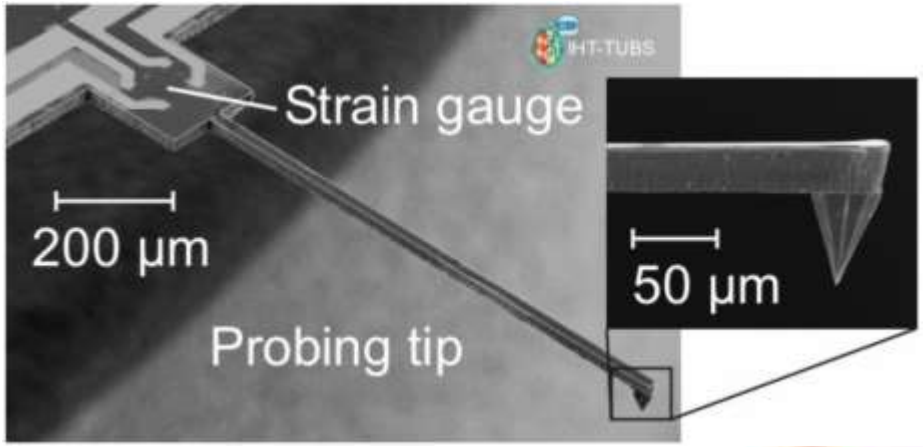
What is EMPIR?

European Metrology Programme for Innovation and Research (EMPIR)

- coordinates research projects to address grand challenges, while supporting and developing the SI system of measurement units
- **innovation activities to target the needs of industry and accelerate the uptake of research outputs**
- enables European metrology institutes, industrial and medical organisations, and academia to collaborate on a wide variety of joint research projects within specified fields: industry, energy, environment, health, SI Fundamental, Normative, Research Potential, and Support for Networks and Support for Impact projects
- annual EMPIR research calls between 2014 and 2020 are supported by 600 M€ of European Union funding
- running call 2019: on Energy, Environment, Support for Networks, Normative, Research Potential, Support for Impact, Research Mobility Grant
- last call in 2020 on Industry topics

Motivation: Development of fast piezoresistive Silicon microprobes (µP)

Idea:
low mass micro-probes →
low inertia →
low dynamic forces
→ high-speed measurements



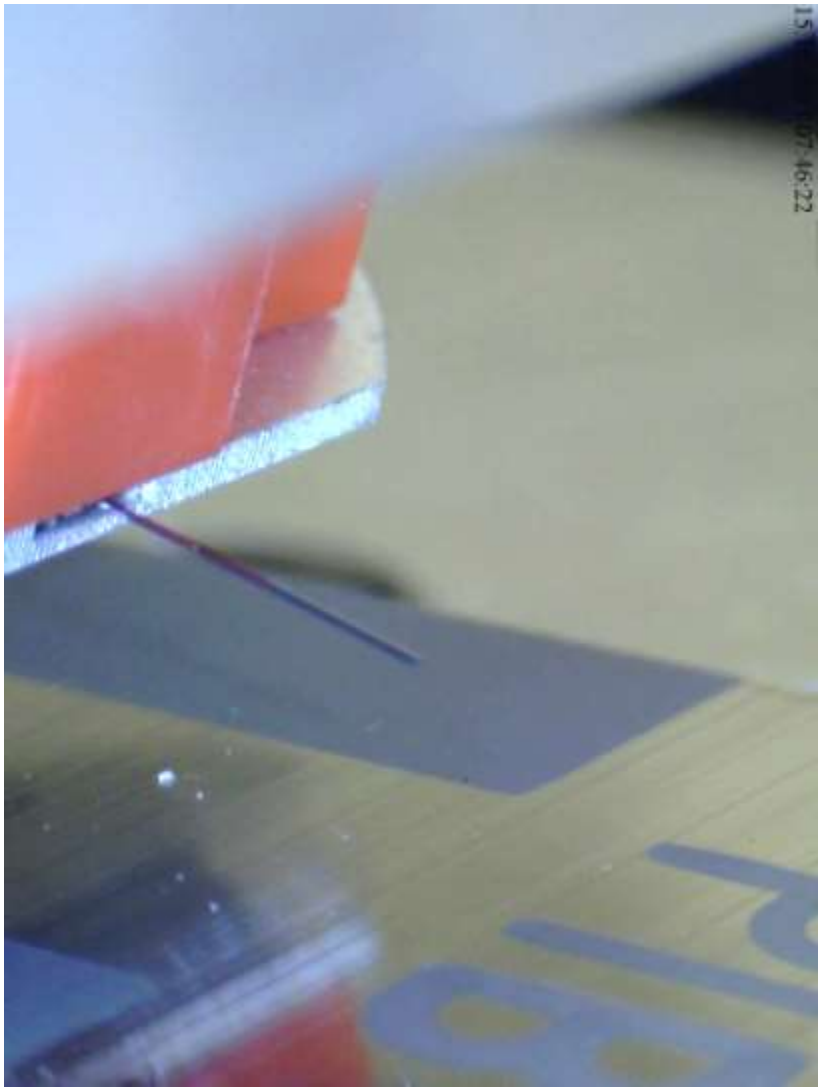
Brand, U.; Xu, M.; Doering, L.; Langfahl-Klabes, J.; Behle, H.; Bütefisch, S.; Ahbe, T.; Peiner, E.; Völlmeke, S.; Frank, T.; et al. Long Slender Piezo-Resistive Silicon Microprobes for Fast Measurements of Roughness and Mechanical Properties inside Micro-Holes with Diameters below 100 µm. *Sensors* **2019**, *19*, 1410.

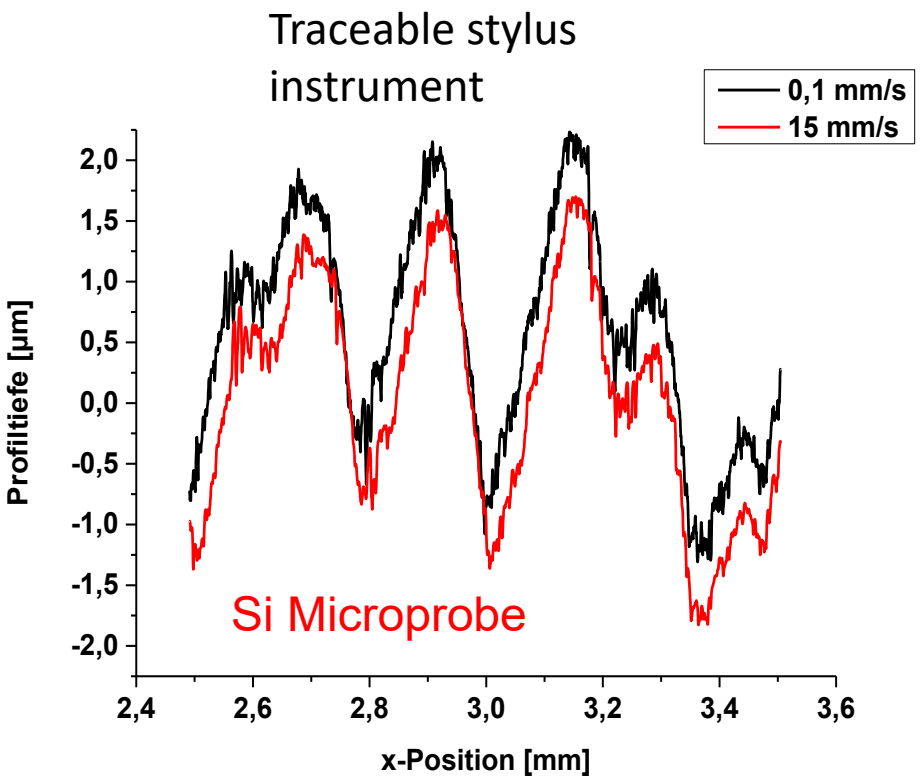
Three different types are available			
	1	2	3
Length / mm	5	3	1,5
Width / µm	200	100	30
Thickness / µm	50	25	25
Max. deflection / µm	220	160	40
Stiffness N/m	8,5	2,8	9,1
Sensitivity µV/ nm	0,24	0,19	0,31

Developed in cooperation with

- the institute for Semiconductor Technology (IHT) of Braunschweig TU (Prof. Erwin Peiner)
- and the Forschungsinstitut für Mikro-sensorik GmbH (CIS), Erfurt (Dr. T. Frank)

Maximum traverse speed: 15 mm/s





Doering, L.; Brand, U.; Bütefisch, S.; Ahbe, T.; Weimann, T.; Peiner, E.; Frank, T. High-speed microprobe for roughness measurements in high-aspect-ratio microstructures. Meas. Sci. Technol. 2017, 28, 034009

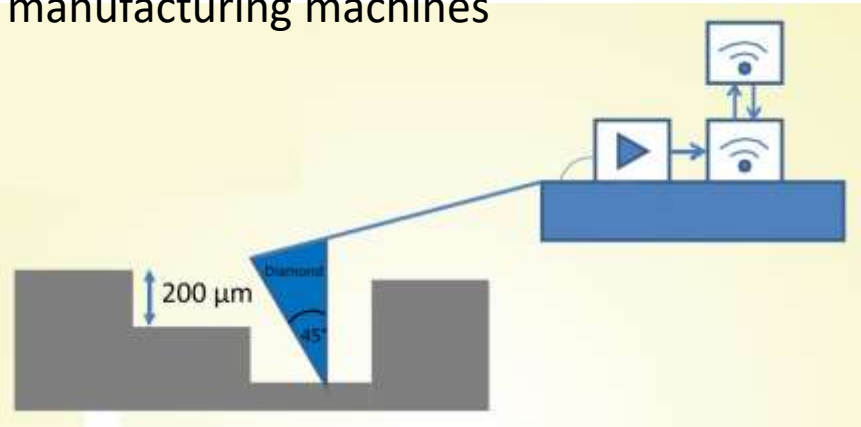
Challenges

- Vibrations on machines → insert damping
- cooling lubricants on machines → sealing of µP
- abrasive wear particles → surface cleaning with compressed air
- large temperature variations → T-sensor on µP
- wear of tip → diamond coating / full diamond tips
- ultra-fine roughness measurements Rz < 0.1 µm → damping
- process times between 5 s and 10 s → high speed measurement
- micro-form meas. with U = 50 nm → diamond tips + cal. standards

EMPIR 17IND05 Multifunctional ultrafast microprobes for on-the-machine measurements (MicroProbes)

Need

Fast multifunctional measurements on manufacturing machines



Idea

Bring piezo-resisitve microprobes onto manufacturing machines for

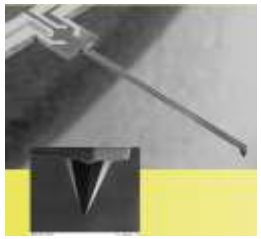
- fast micro-finish measurements (flatness, waviness, roughness, micro-form) and
- fast mechanical measurements (elasticity (E), layer thickness, adhesion, wear) using contact resonance (CR) and force-distance curves (FDC)

and

Develop new industry-compatible micro-probes with

- wear resistant diamond tips (r ≤ 2 µm)
- higher z-ranges up to ± 200 µm and
- a damping of d ≈ 0.5

Duration: 3 years until 30th May 2021



Objectives

1) PTB: develop prototype microprobes for the **fast measurement of topography and mechanical properties** including tip characterization (U = 50 nm), morphological filtering, setting probing forces (→ *Heinz Behle*)
2) TU BS: **develop new large deflection, high-speed, low tip-wear micro-probes** with pre-deflection, damping, integrated actuator (→ *Michael Fahrbach*)
3) BAM: develop validated methods for the measurement of enhanced surface properties on-the-machine including adhesion, thickness of liquid films, detection of contaminants, measure elastic-modulus using **contact resonance and force-distance curves** (→ *Sebastian Backes)*
4) develop validated methods for the **integration of these µP into manufacturing machines:**
   - micro-finishing machines (→ *Sebastian Goeke*/Thielenhaus Technologies)
   - roll grinding machines (→ *Tuomas Lindstedt*/Roll Research International)
   - wear testers (→ *Timothy Kamps*/NPL)
   - miniaturized MicroProfiler with an integrated feed unit (→ *Michael Drexel*/Breitmeier)
5) Up-take of technology, measurement infrastructure (calibration standards, methods for traceable micro-probe measurements on-the-machine) by the measurement supply chain (manufacturers of machines, standards developing organisations and end users).