From Nanorobotics to Microproduction

... Know-how transfer between dimensions

Klocke Nanotechnik

One of 279 members in a Microtechnology Network
Modular Nanorobotics

Configuration instead of Development

Pool of more than 200 Nanorobotics Components

- Configuration to individual machines

- \( \mu \)-Assembly, \( \mu \)-Tensile-Machine, 3D-Nanofinger, SPM-Lithographer, ...

- The SEM/FIB Workbench

- Integration in Nanorobotics systems

- Universal Testing Benches

- Micro Production Systems
Nanorobotics

5 - 50 mm stroke
Loads up to 2 Kg
1 nm resolution
No backlash
Microassembly-Module
with < 1 nm resolution

Microgripper with 1 nm resolution and different tip shapes

Microgripper

Force sensor
A new instrument between Profilometer and Coordinate Measuring Machine
• 3D Topography

- Contours

- Dimensions

- Angles

- Roughness

- Stroke:
  Up to 50 mm in XY and 20 mm in Z

- Resolution of movement: 1 nm
  Sensor resolution: 0.5 nm
  Smallest structure size: < 100 nm

- Automation
1 Example

Measurements in small holes

Internal screw thread with 1.4 mm diameter

Linescan to determine the winding angle
The SEM-FIB Workbench

Handling in SEM/FIB, as easy as at a Light microscope:
The SEM-FIB Workbench

Applications

Color = exclusive applications of Klocke Nanotechnik

Electron / Ion Microscopy Applications
4 Nanorobotics Manipulators

Typical SEM-Integration
The in-SEM “NanoFab”
Automatic microassembly of smallest components

- Production of Carbon Nanotube transistors
- AFM tips sharpened by CNTs
- Production of GHz antennas ...

The “NanoFab” from Klocke Nanotechnik in a network of partners:
The “NanoFab” in your SEM

... including several different Microgripper series
Electrostatic Gripper
Force Feedback Gripper

Kraftsignal

10 Hz Dreieck
Force Measurement

Haptic interface
Nanoassembly of Carbon Nanotubes

Handling & assembly of a CNT with 2 manipulators

Assembly of a CNT at an AFM-Tip

Handling & assembly of a CNT with a microgripper
Particle sorting
Particle sorting
In-SEM development
Probe Card Repair
In-SEM development
Probe Card Repair

Live Image Positioning:
Select target

1D-Nanofinger®:
finds target, measures position

Tip:
bending tests
In-SEM development
Probe Card Repair

1D-Nanofinger®:
finds soft target
Bending Experiments

In-SEM development
Probe Card Repair

D1 = 64851.38 nm
The bridge between Nanotechnology and mechanical Engineering:

Production island with Nanometer-resolution for up to Kilograms of load

Operation modes:
- Manual mode with Joysticks
- Automatic functions & manual operation
- Completely automatic process
- Closed loop process with vision control
1. High precision xy-stage

2. Nanorobotics modules [2], microgripper, Nanofinger, Wafer Prober, ...

3. Two rotation stages for source and target area

4. Adhesive dispenser, Nanomanipulators, Scanning Probe Microscopes, MicroProf®

5. Video cameras with vision software for pattern recognition

Flexible System Configuration

From Nanomanipulator with Gripper up to:

The most precise production cell available in the market:
- 3D Microassembly and interconnection technology, e.g. including:
- Micro Adhesive Bonding, Pattern recognition and Quality Control

... or a "Universal Testing Bench":
- For analysis, quality control, reverse engineering, prototyping and repair, incl.:
- Nanomanipulators, Wafer Prober, Force Sensors, Inspection Systems for:
- I/V or force measurements, failure analysis, prototype development or repair

... or both, configured by yourself:
- Choose components out of a wide range of our kit, we deliver that special system.
- Change and add components later as you like

In any case:
- It's 10 – 100 times more precise than other solutions!
Resolution of the Base Stage

Test in Scanning Tunneling Microscope mode:
Z-axis of an STM fixed at the bridge
XY-movement made with the base stage

=> 3D image of CD bits

Noise in the image: about 50 nm!
First Expansion Step
with 1 nm resolution
Second Expansion Step
Including Automation
Second Expansion Step
with more D.O.F.

- Base stage: X, Y, rotation
- 2 XYZ Manipulators
- 3 different Microgrippers
- Micro adhesive bonding dispenser
- Micro Tensile Testing modules
- Wide range zoom video microscope
- High resolution video microscope
- 3 Cold light sources
- Sequencer for automation
The small System
... with 100x100 mm² Stroke
Nanorobotics:
50 mm X
2x 50 mm Y
Up to 5x 20 mm Z
Vertical & hor. Microgripper
Micro Adhesive Dispenser
Microgripper at 45°
... some components

Birdview Camera
HiRes Camera
FRT MicroProf
Nanorobotics
Drive e.g. for Glue dispenser
Inspection Camera

Nanorobotics
Drive e.g. for Glue dispenser
…including Micro Adhesive Bonding,

- Joining of many different materials
- Multi-functionality of the joint (e.g. mechanical fastening plus conductivity)
- Low heat / cold joining
- Low mechanical stress, uniform stress distribution
- Galvanic isolation of the parts (no contact corrosion)
- Small solutions and new freedom for design

Endoscope Objective, Ø 1.85 mm (Wolf GmbH)

VCSEL diode after active alignment glued into SMD housing. Coupler to glass fiber (Spinner GmbH)
... with Pattern Recognition of single pixels
For current measurement

... probe tip approach
... Current Measurement

![Graph showing current measurement for NMOS with different gate voltages (Ug = 0 mV, 500 mV, 1000 mV, 1500 mV, 2000 mV). The graph plots Ids [μA] versus Uds [mV] with three probe tips.](image-url)
On arrays in automatic measurement: Alignment by pattern recognition
... Force-Distance Diagrams at Microstructures
... Nanoindentation to form structures

Depth measurement for each indent
... Nanoindentation
measured with the 3D-Nanofinger

Profilometer Linescan
Imprints in Cr

Zoom of right end
974 nm
10 μm

Zoom of left end
912 nm
10 μm
Grinding of a wedge structure into Silicon
... or Automatic Microassembly
e.g. to "sharpen hairs"
e.g. Microassembly of RF-Modules

- Nanomotor-Gripper
- Microgripper

- Beam splitter
- Waveguide-horn
- Copper block
- Fixed waveguide-termination
- Substrate channel
- Bond-contact to IF-amplifier and DC-Bias
- 10 mm Z
- 20 mm * 20 mm xy

- SIS 800 GHz
- RF 809 GHz
- LO 808 GHz
- Superconducting heterodyne detector
- Local-oscillator
- Microstrip
- IF-low-pass
- Antenna + mixer
Micro Production Systems:

Link:
http://www.nanomotor.de/aa_production_system.htm

Strength:
- flexible configuration, also by user
- ideal for changing production tasks
- Flexible upgrade options avoid investment risks

Weakness:
- not developed for single type mass production (.... ?!)
Micro Production System
for mass production

Glass fiber assembly
in
mass production:

500-700 good parts
per week
**Micro Production System**
First Prototype, upgraded to Service machine

Produced 24,250 good parts: 400-500 per week

Made for first process development
All commercial dispensers failed => own development
Micro Production System
Production machine

… just a box …
Micro Production System
Production machine

Degree of Automation…
Micro Production System
Production machine

What’s inside?
Micro Production System
Production machine

View at the machine without housing
Micro Production System
Production machine
Micro Production System

Specification

• 87 good parts per day
• Cycle time < 3,5 minutes
• Yield > 80% measured during production
• Light point position +- 5µm
• Adhesive & fiber position error < 2µm at 15mm length
• Axial Fiber rotation < +-5°
• Varying fiber diameter: 27µm - 45µm

• Several different pre-defined production processes
• Data base interface
• Remote service
• Operation possible by „everybody“
• Replacement machine ready in < 3 days
Micro Production System

D.O.F.

3 Cameras
17 Degrees of Freedom

Gripper: x, y, z

Dispenser: x, y, z

Fiber: x, y, z, \(\theta\), \(\varphi\), \(\phi\)

Target: x, y, z, \(\theta\), \(\varphi\)
Micro Production System

Coordinate systems

Automatic Calibration

Nanorobotik

Nanotechnik

Klocke

Micro Production System

Coordinate systems

Automatic Calibration

Nanorobotik

Nanotechnik

Klocke
## Micro Production System

### Data rates and precision

<table>
<thead>
<tr>
<th>Description</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>256 gray scales with 1280x1024</td>
<td>1.3 MB</td>
</tr>
<tr>
<td>30 pictures per second</td>
<td>39 MB/s</td>
</tr>
<tr>
<td>4 Cameras</td>
<td>156 MB/s</td>
</tr>
</tbody>
</table>

\[ = 1.25 \text{ GBits/s} \]

Bandwidth must be dispersed to the cameras, depending on speed and optical parameters.
Micro Production System

Positioning the target structure

Angle correction: -0.4855°
Axes: z1, z2
Micro Production System

Positioning the target structure

Position correction: +68800nm, -57432nm
Axes: y, z1, z2
Micro Production System

Positioning of Fiber

Angle correction: Axis: $\theta$
Micro Production System

Positioning of Fiber

Position correction: Axes: x, y, z
Micro Production System

Positioning of Fiber

Correction of rotation
Axes: x, y, z, $\phi$
Micro Production System

Positioning of Fiber

Correction of fiber end Axes: y, z
Micro Production System

User interface

Selection of production type or service tasks

Wizard reminds user

Process result

Wurden Faser und Absehen eingelegt oder soll die Produktion beendet werden?

Produktion
Absehen Typ | Duralyt
Bediener | klocke
Auftrag | demo

Produktion starten
Ruheszustand

Wartungsintervalle

Klebstoff | 94 h
InspektionH | 820 h
InspektionS | 9398 Stück
Aceton | 23 h

test

Ausschuss

Ereignisse dieses Prozesses


Kommentar

Faserabsehen ennommen

...
**Micro Production System**

Database interface

ErP data base interface for automatic storage of process parameters, pictures, movies...
Micro Production System

The assembly process

Process Control

Hardware

Click 2 times onto this background to see the movie
Complete Micro Production Line

Organisation:
VDMA

IBM

Laser & Electronics

IFAM
Institut Fertigungstechnik Materialforschung

LPKF Motion & Control GmbH

Klocke Nanotechnik

FRT Fries Research & Technology

Live!
Micro Production Line

Applications Integration Handling Automation MicroPref Micro Adhesive Bonding Nanobotics Modular Control System Lasermicro-structuring
Pool of more than 200 Nanorobotics Components

Configuration to individual machines

µ-Assembly, µ-Tensile-Machine, 3D-Nanofinger, SPM-Lithographer, ...

The SEM/FIB Workbench

Integration in Nanorobotics systems

Universal Testing Benches

Micro Production Systems

Summary

Modular Nanorobotics