Smart Sensor Systems
Intelligente Sensorsysteme

Prof. Olfa Kanoun

Chair for Measurement und Sensor Technology

Faculty for Electrical Engineering and
Information Technology

TECHNISCHE UNIVERSITÄT
CHEMNITZ

Presentation

My name is....

from ....

I have studied ………..... before the Master

I'm Interested by this master because of ......

MST-Team

Research @ MST

- Batteries, Hi-caps
- Characterization and modelling
- Interaction with application (e-mobility, smart grids, electric devices)
- Online Diagnosis

- Energy Harvesting
- Energy Transmission
- Energy Management
- Applications: smart home, industry,

| Characterisation of Energy Storage Units	Novel Measurement Methods
Energy Autonomous Sensor Systems	Novel Sensors
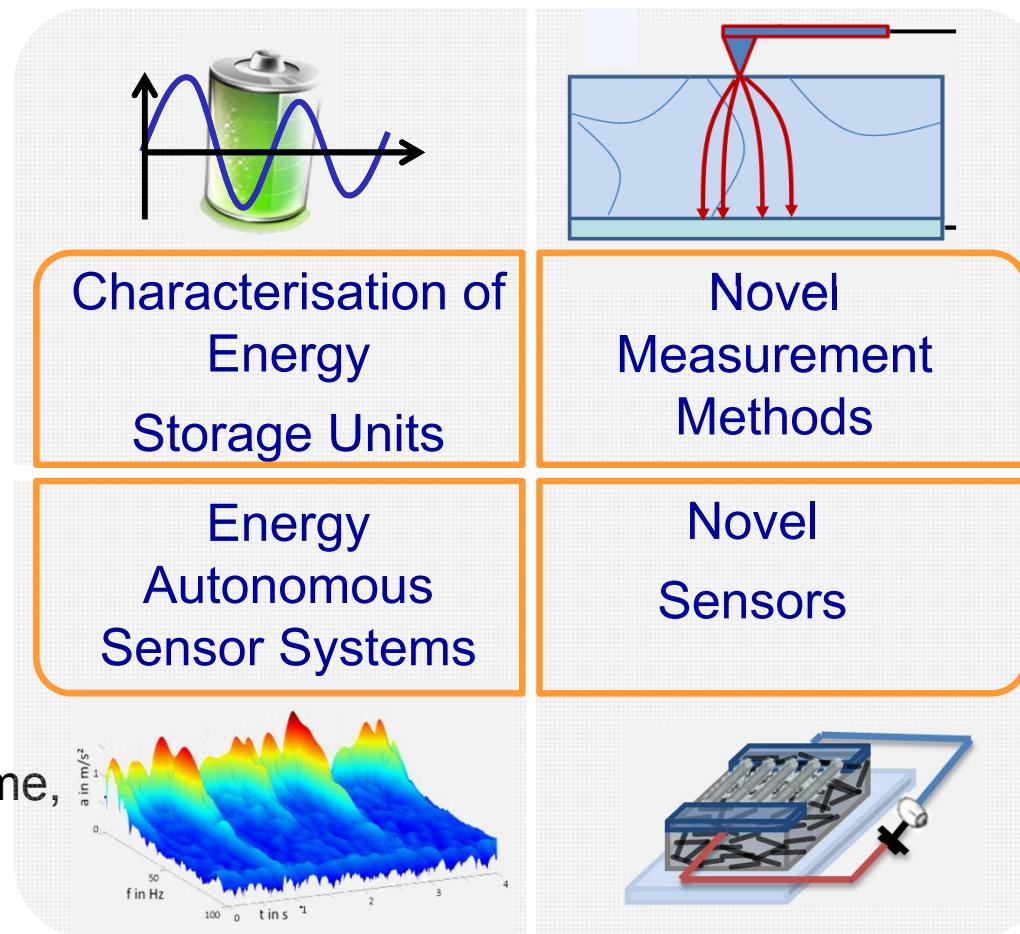
- Characterization of materials and systems
- Modelling and signal processing
- Multifunctional sensors
- Macroscopic and microscopic analysis

- CNT based sensors
- Eddy current sensors
- Conductivity sensors
- Capacitive sensors

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S. 0-4

Education @ Chair for Measurement and Sensor Technology

3rd Semester   5th-6th Semester   7th-9th Semester

                                                        Master

Electrical Measurement

ET, IKT, MTM   3 SWS (WS)

Smart Sensor Systems

ET, MNS, MMS, MP   4 SWS (WS)

Sensors and Signal Pre-Processing

ET/IKT   3 SWS (WS)

Sensor Signal Processing

ET, MNS, MMS, TM   4 SWS (WS)

Photonics

MNS   2 SWS (SS)

Automotive Sensors

MNS, MP, ASE   2 SWS (SS)

Energy Storage Systems

EET,, EM   4 SWS (SS)
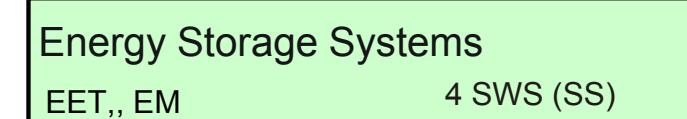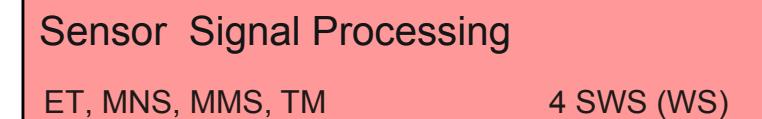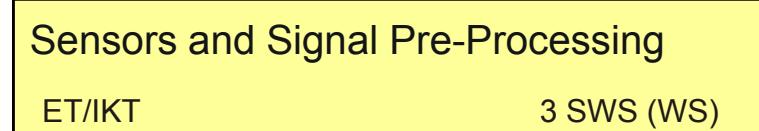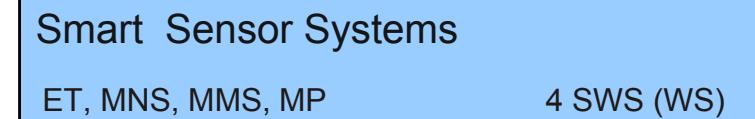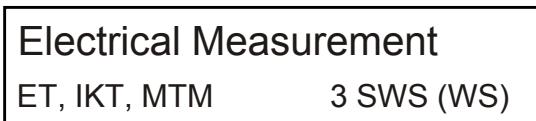
Project Laboratory, Bachelor Thesis, Master Thesis

All students, cooperation with industry

Key Role of Instrumentation Systems

Industrial

Automation

Quality Improvement

Control Effectiveness

Diagnosis

Comfort

Monitoring

Security
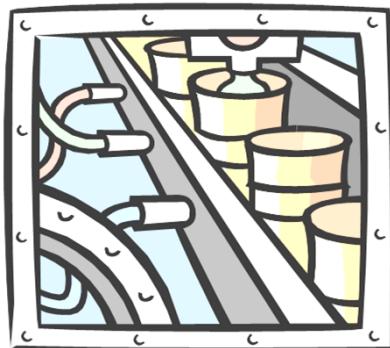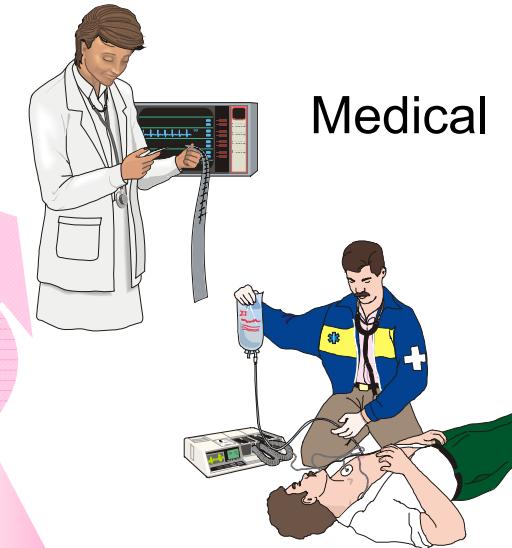
Medical

Automotive

☁☀ Smart Home

CO_2
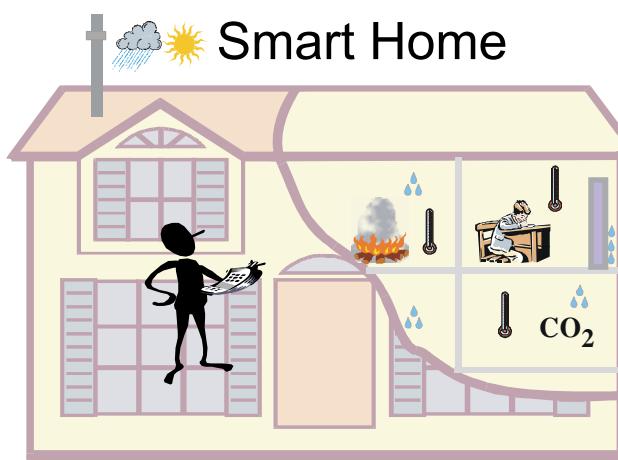
Consumer, Military, Nautical, Aeronautical, Robotics, ...

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S. 0-6

World market for sensors – a big business

GLOBAL MARKET FOR SENSORS, 2009-2016
($ MILLIONS)
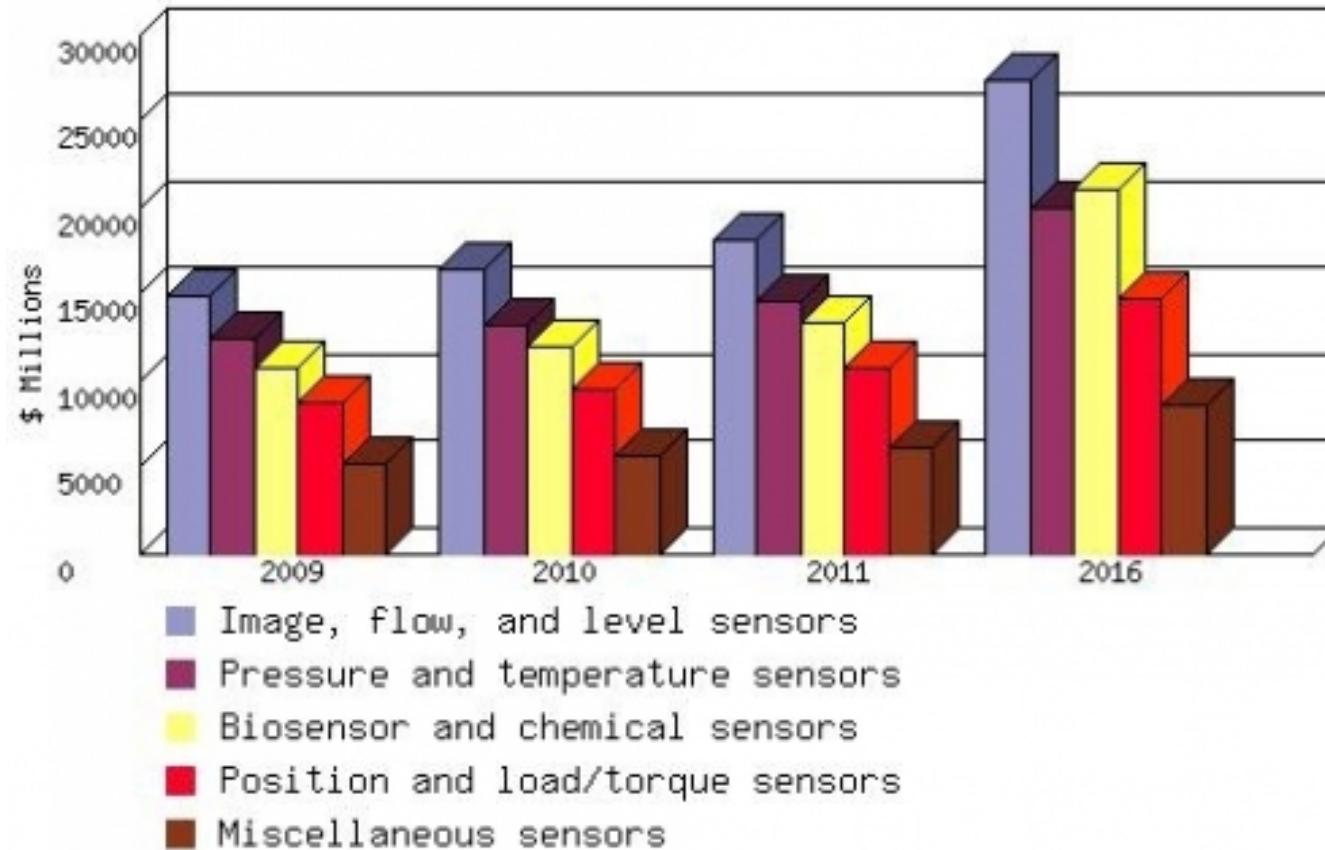
$62.8 billion in 2011 and and expected to increase to nearly $91.5 billion by 2016
→ annual growth rate (CAGR) of 7.8%.

Source: BCC Research

World Markt for Sensors

Top Ten of Sensor Types After Market Share:

1. Temperature Sensors
2. Absolute Pressure Sensors
3. Flow Sensors
4. Proximity Sensors and Swiches (Light Barriers, Proximity)
5. Position Sensoren
6. Chemical Sensors in Fluids
7. Filling Level and Difference Pressure Sensors
8. Velocity and Rotation Sensors
9. Chemical Gas Sensors
10. Chimney and Fire Sensors

Top Ten ofSensors with the highest growth rates:

1. Rain Sensors
2. Thickness Sensors
3. Fluid Purity Sensors
4. Navigation Sensors
5. Inclination Sensors
6. Photo Detectors
7. Glas Braking Sensors
8. Biosensors
9. Magnetic Field Sensors
10. Movements Detectors

Quelle: www.intechnoconsulting.com

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S. 0-8

Intelligence is relativ.
It is an Expression of Progress!

What is Intelligence?

Intelligence is to understand, to communicate and to profit from earlier experience in dealing with new situations, …

- Knowledge, memory, ability of finding
- To understand, to think and to realize
- Ability to speak
- To do tasks effectively and quickly
- To profit from earlier experiences in dealing with new situations
- ….

Information

Information Processing

Communication

Effectivity (costs to benefits)

Self adaptive

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Smart Sensors

[Schwerdtfeger, 1939]
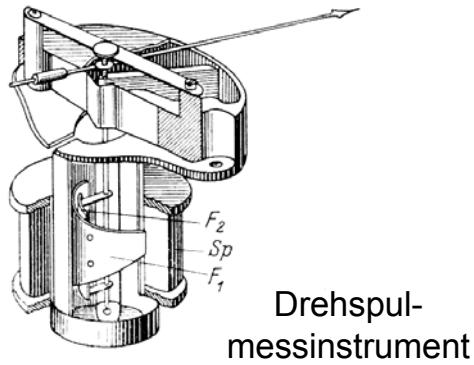
Drehspul-messinstrument
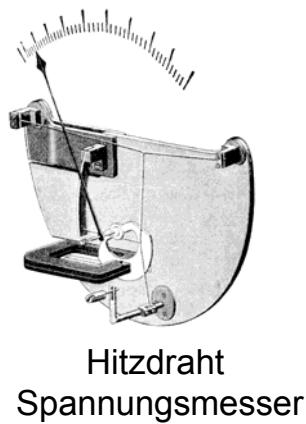
Hitzdraht Spannungsmesser
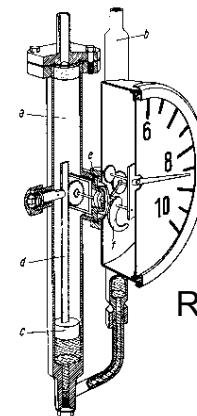
Radizierer
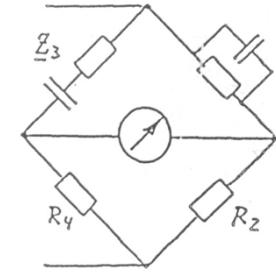
Bridges

Contains
Signal Processing

70ty Years

Integrated
1-chip Realisition

[J. E. Brignell, University of Southampton, UK, 1989]
... The suggestion was greeted with some scepticism:
- Costs
- Complexity

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Smartness of Sensor Systems

Compensation of annoying effects	digital Communication Interface	Micro Electronic
plug-and-play • Self Test • Self Calibration	Wireless Communication	Microsystem Technology
get better Information	Energy Autonomous (Energy Harvesting)	Nano Technology
Optimized Information Extraction	Flexible System Integration	Include New Technologies
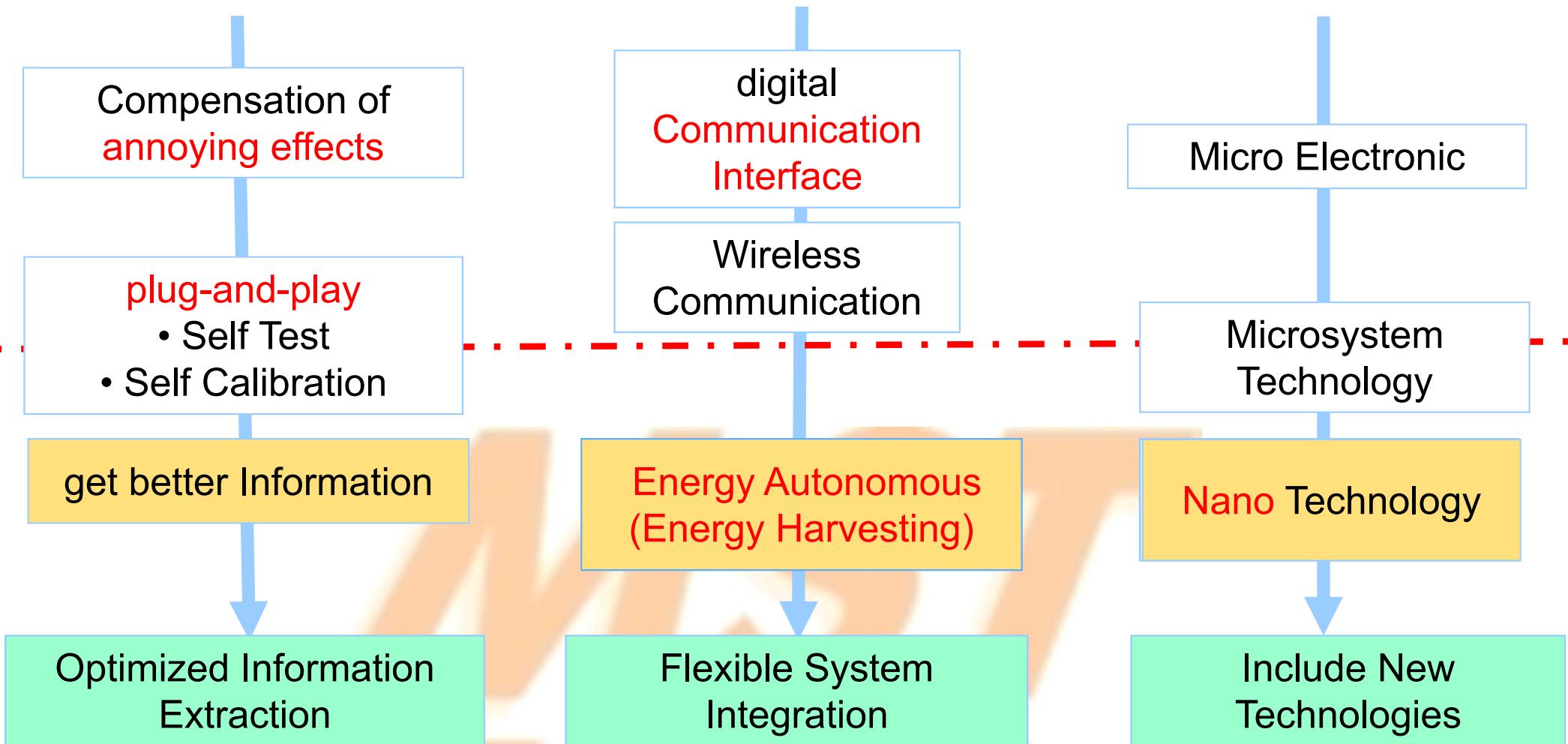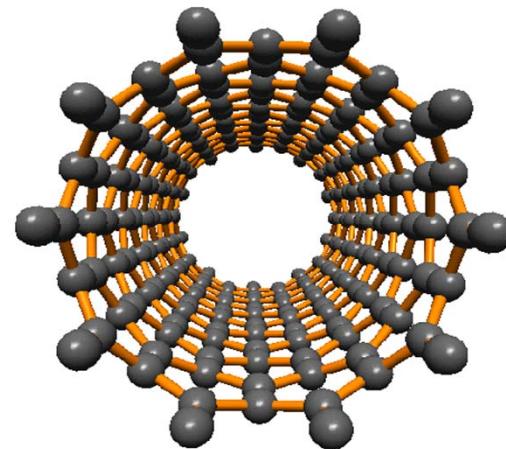
Carbon Nanotube Sensors

**Fundamental Research**
Applied Research

Carbon nanotubes (CNT)

Properties of CNTs

Electrical → metallic and semiconducting

1000-current density higher then copper

- − Percolation threshold in polymercomposites < 1 wt%

- − High aspect ratio, l/d (~10^4 bis ~10^7)

- − Large surface area
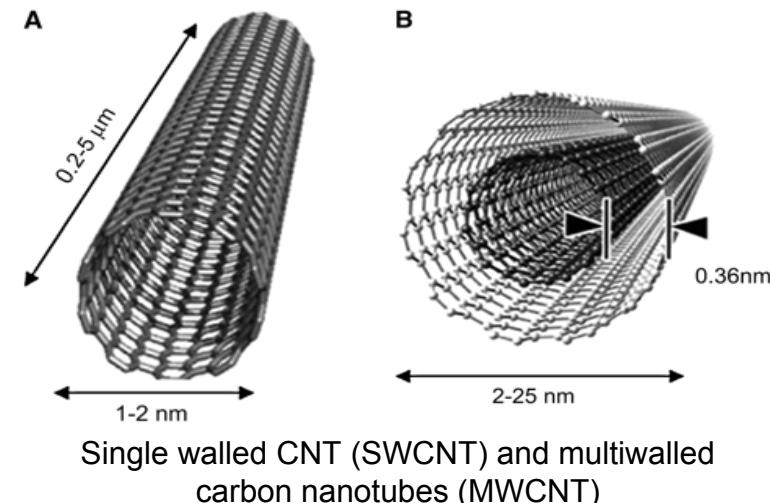
Single walled CNT (SWCNT) and multiwalled
carbon nanotubes (MWCNT)

Material	Young's Modulus (GPa)	Tensile strength (GPa)	Density (g cm^{-3})
SWNT/MWNT	≈ 1000	≈ 100 – 200	≈ 0.7 – 1.7
High tensile steel	210	1.3	7.8
Carbon fiber	230	3.5	1.75
Glass fibers	22	3.4	2.6

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Road-map to CNT- sensors

CNT
- SWCNT
- MWCNT

CNT Dispersions
- Surfactant
- Polymer
- Functionalization

Characterisation → • Dispersion quality..........

Film Deposition
- Drop-Casting
- Spin coating
- Inkjet printing
- Screen printing
- Dielectrophoresis

Characterisation →
- Morphology
- Electric properties
- Elasticity
- Film thickness
- ....

Applications
- Strain
- Pressure
- Light
- Sensor matrices

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Deposition methods

- Drop-Casting
- Spin Coating
- Dielectrophoresis
- Printing
  - Inkjet
  - Off-set,…

Drop casting

Spin coating

Screen printing

Imaging signal

Substrate

Piezoelectric ceramics

Ink

Nozzle

Inkjet-Printing

Dielectrophoresis

CNT-Film by Spin Coating

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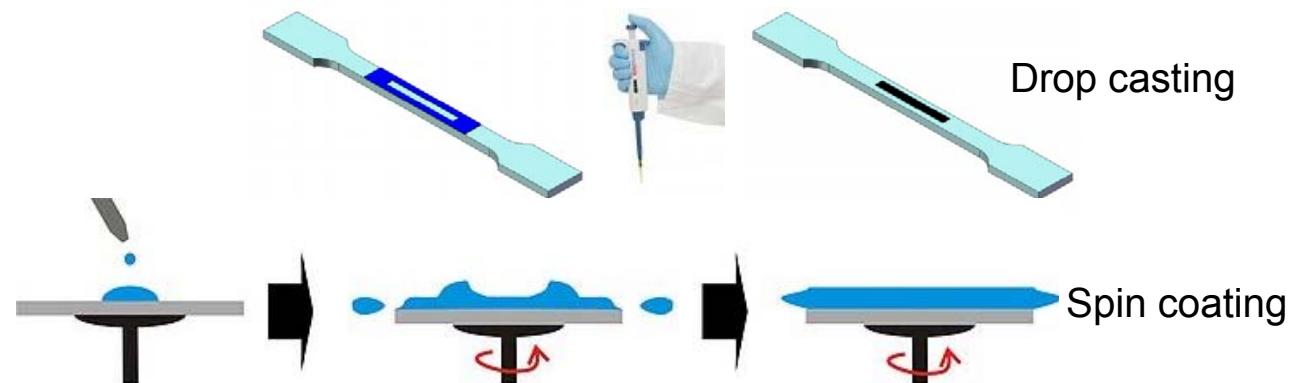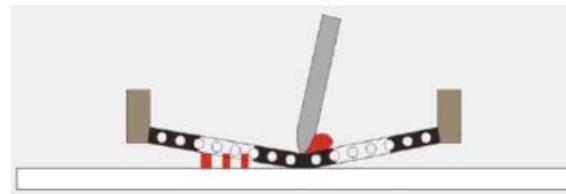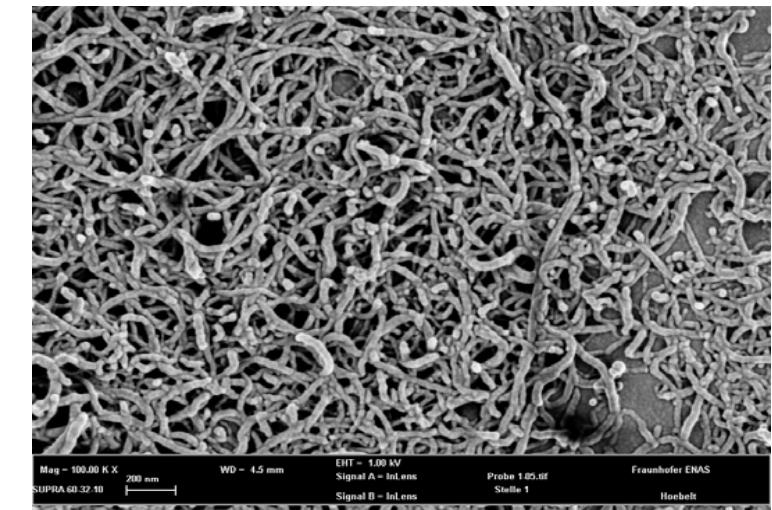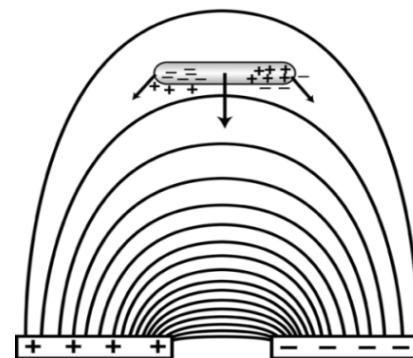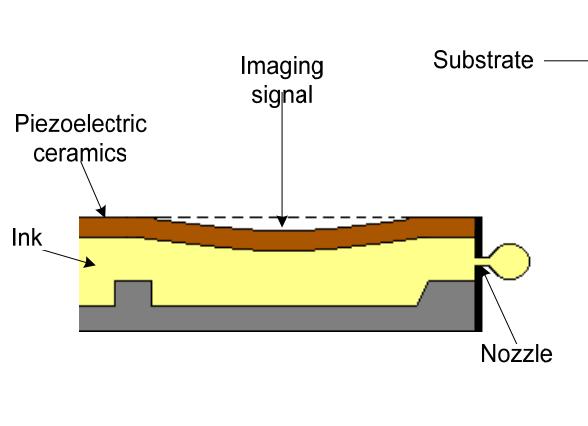
CNT strain gauge

Advantages over metallic strain gauges

- Higher sensitivity
- Large measurement range ($\varepsilon_{max} \approx 6\%$)
- Application without adhesive
- Tunable behaviour
- Versatile application methods (drop casting, Ink jet printing, spin coating, layer by layer…)

## Sensor principle
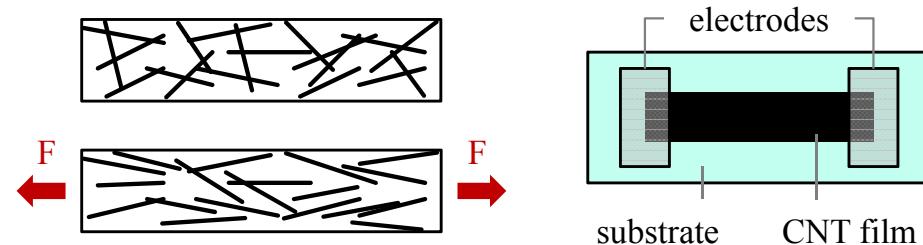
Experimental results
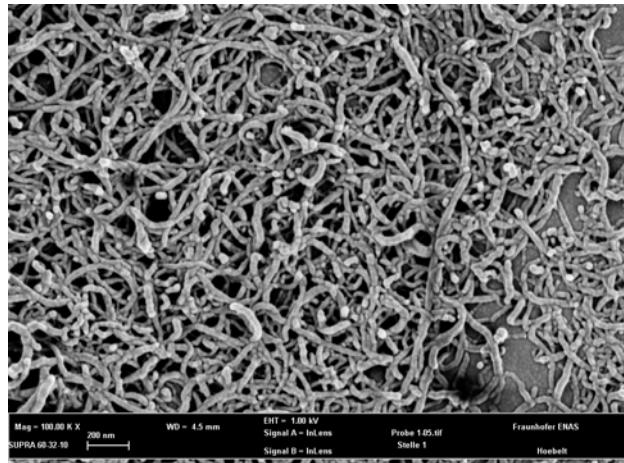
CNT-film by spin coating
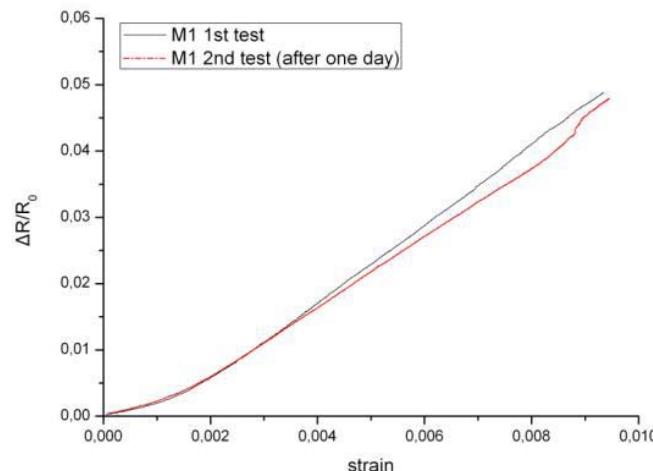
Relative change in resistance verse strain of a drop casted MWCNT film

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S. 0-17

Structure of Sensor System (1)

Influence Factors

Measured Quantity → Sensor Element

Over Voltage Protection

Circuit of Operation
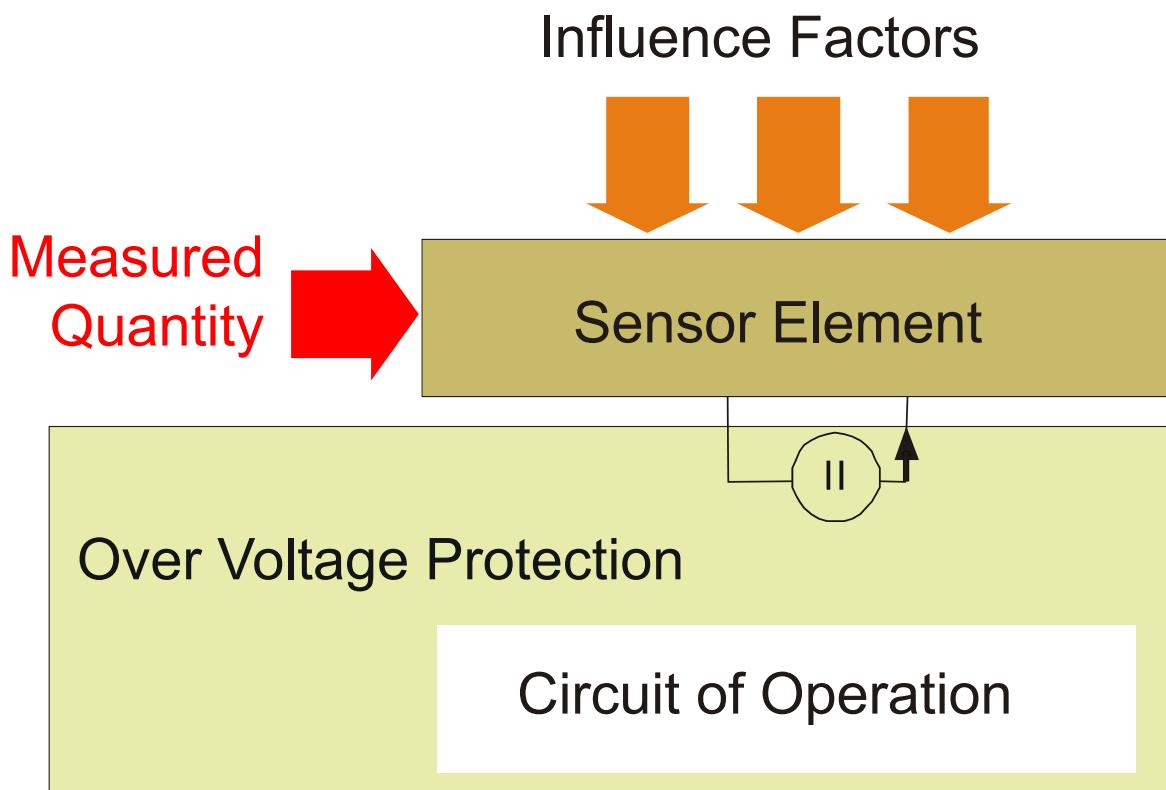
- Power supply
- Adjusting of operating conditions
- Special measures for the secure operation

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S. 0-18

Structure of Sensor System (2)

Analog Signal Processing

Sensor Interface

Influence Factors

Measured Quantity → Sensor Element

Over Voltage Protection

Circuit of Operation

Amplification
Linearization
Signal Conversion
Scaling

Amplitude Frequency

A/D-Converter
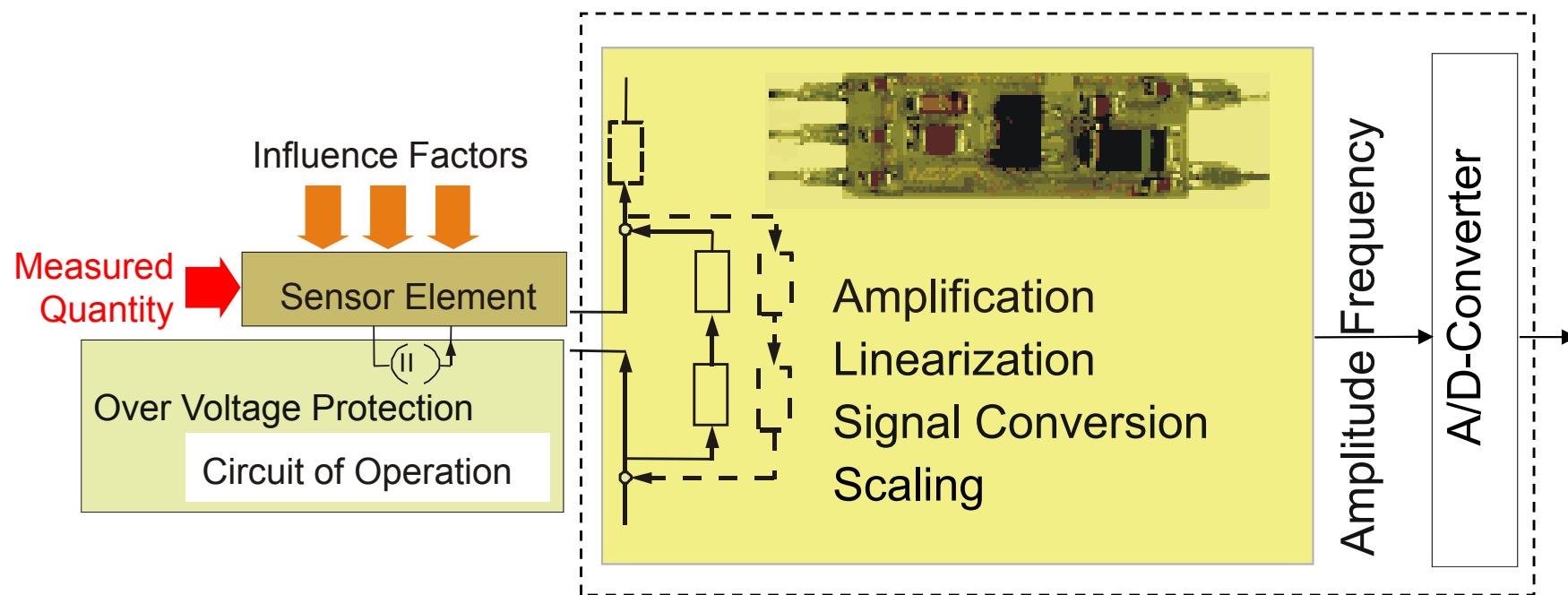
Local digitalization of the sensor signal

➡ slight precision loss independently of the distance between the sensor and the higher processing unit.

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Structure of Sensor System (3)

Digital Signal Processing

Model

Influence Factors

Measured Quantity

Sensor Element

Sensor Interface

Calculation of the Measured Value

Correction of:
- Influence Factors
- Manufacturing Tolerances
- Aging Effects

Measured Value

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S. 0-20
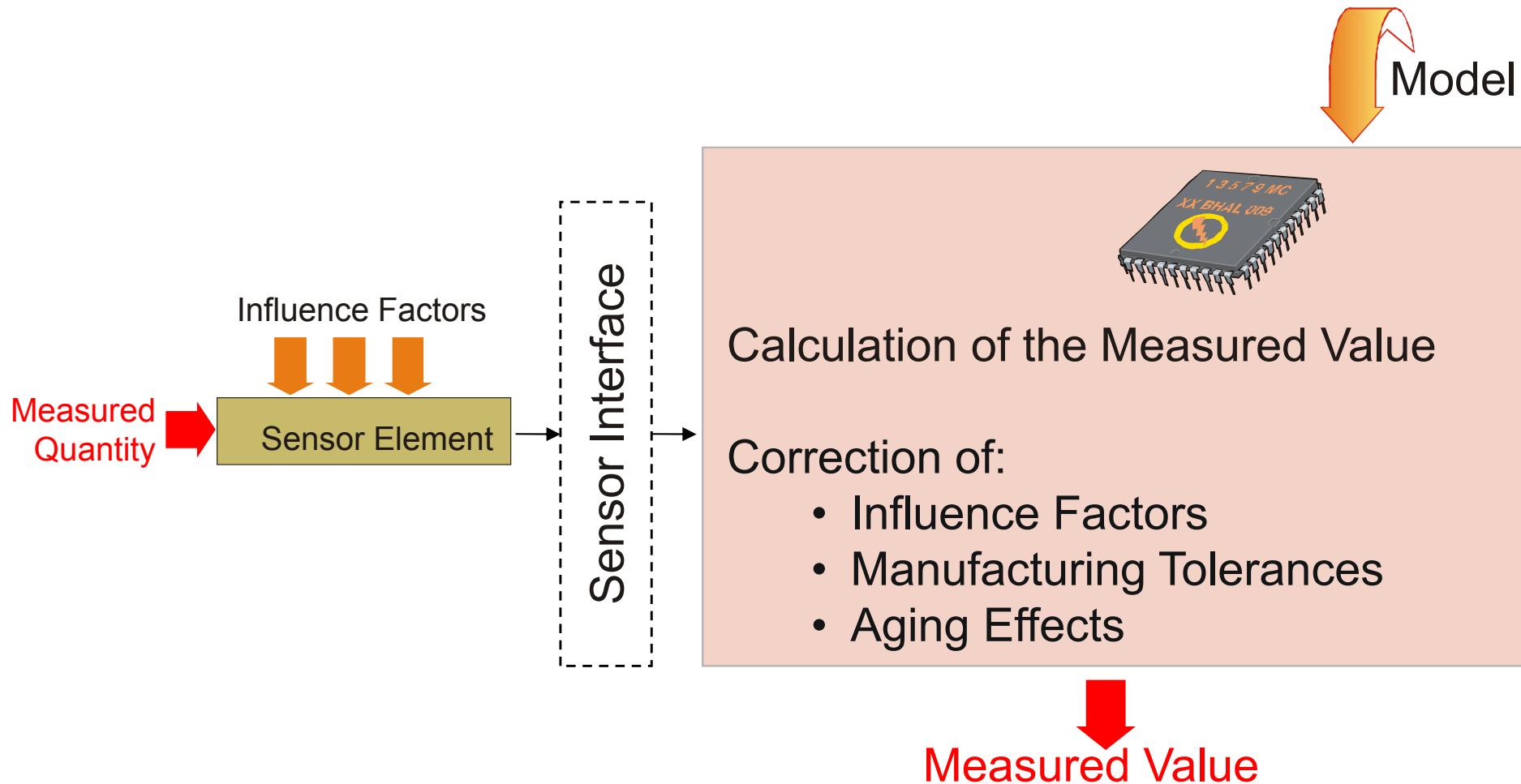
Aims of the Course
Smart Sensor Systems

- Sensor properties, sensor technology

- Sensor signals and disturbing effects

- Design of sensor systems

- Selection of operating conditions for sensors

- Data acquisition and analog interfaces

- Analog-Digital-Conversion

- Impedance spectroscopy

Smart Sensor Systems

Course: Tuesday,   11.30 – 13:00,   2/N010

Exercise: Monday,   09.15 – 10.45,   2/N013

Team

Dipl.-Ing. A. Fendri   Dipl.-Ing. I. Chaour   Dipl.-Ing. (FH) F. Ebert

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