Development of textile-based sensors for inspection of composite materials„

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Introduction

- **Applications for composites**

- **Monitoring of mechanical deformation and damage is demanded**

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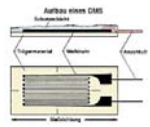
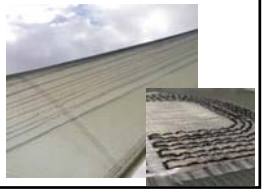
State of the art

- **Established sensors (Strain gauges, optical sensors : large areas outside of the measuring cell remain unconsidered)**
  - **Strain gauge**





  - **Sensoric Fibres**
    - **Fibre optical sensors/Bragg grid**
    - **Piezoelectric sensors (PVDF)**

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Objectives

- Development of a large area sensor, individual and arbitrarily dimensioned
- Avoidance of predetermined breaking points

  →Use of textile based sensors
  - Printed sensors (Screen printing, Inkjet printing) on

    Reinforcing textile

    Textile carrier material

    Composite

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Approach

Printing of sensors on reinforcing textile

- Printing of electroconductive interdigital structures as electrodes for recording measuring signal
- Printing/Coating of reinforcing textile using sensor active materials (conduct. Polymers, carbon….)
- Manufacturing of composites (vacuum infiltration)
- Measuring of resistivity or capacitance under mechanical load/bending

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Printing Pastes

Printing paste (Ag)
40% Ag-Flakes
9% Binder
4% Thickener
47% Water

Printing paste (Carbon)
4% Carbon black
5% Binder
1% Thickener
1% Dispersing agent

Paste	Conductivity (Ω/sq)
Silver paste ITCF	~ 1
Carbon paste ITCF	~ 6000
Silver ink (30%Ag)	~ 1…10 (5 OP)
Carbon ink (5%C)	10.000-50.000 (1 OP)

Manufacturing of sensing reinforcing textile

1. Imprinting of electro-conducting interdigital structures/electrodes on reinforcing textile using screen printing or inkjet printing.
2. Coating of electrodes using sensing materials (Carbon..)

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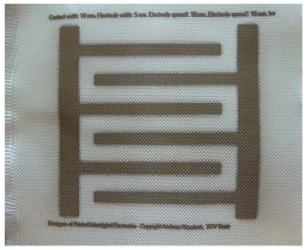
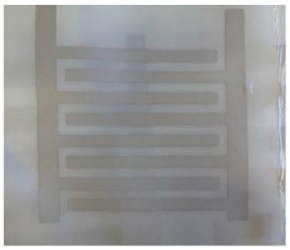
Printing of electrodes on glass fibre fabrics

Inkjet printing with Ag-ink on GF (R< 5 Ohm/sq (5OP)



Screen printing with Ag-paste on GF (R< 5 Ohm/sq)



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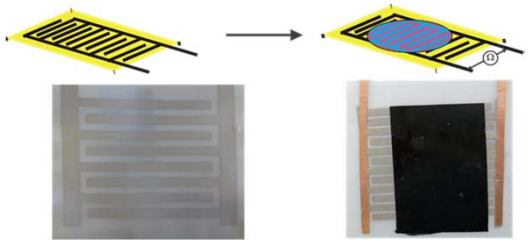
Sensors on Glass fibre fabrics



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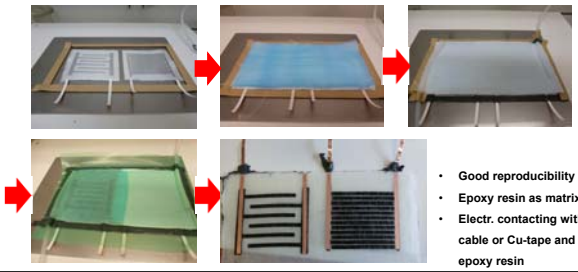
Manufacturing of composites using vacuum infiltration



- Good reproducibility
- Epoxy resin as matrix
- Electr. contacting with cable or Cu-tape and Ag-epoxy resin

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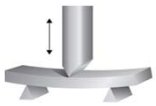
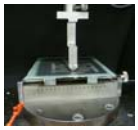
Testing of sensing composite





- Bending test (Zwick apparatus)
  →Reproducible loads
  →Variation of bending speed and amplitude
- Measurement of ohmic resistance (current at constant voltage)

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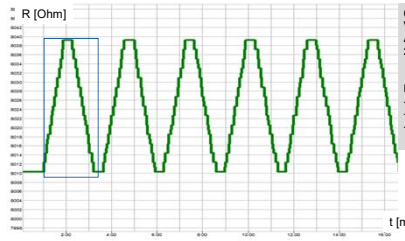
Testing of composites sensing properties



6% C-paste on reinforcing textile
Velocity 5mm/min
Amplitude 5 mm
20 s stop after deformation

Result:
- Periodic signal
- No hysteresis
- Correlation between bending and signal

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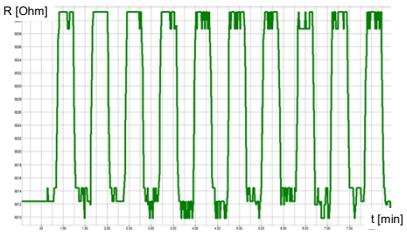
Testing of composites sensing properties



4% C-paste on reinforcing textile
Velocity 100 mm/min
Amplitude 5 mm
20 s stop after deformation

Result:
- Periodic signal
- No hysteresis even at high velocity
- Correlation between bending and signal

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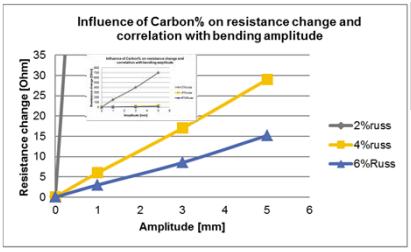
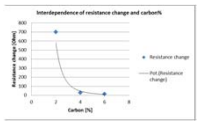
Testing of composites sensing properties



2-6% C-paste on reinforcing textile

Result:
- **Linear correlation of bending amplitude and resistance change**
- **Low carbon% results in high resistance change**



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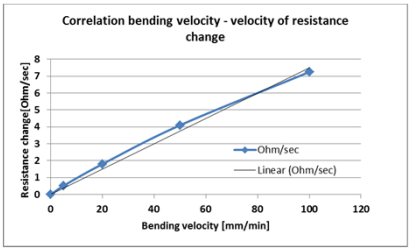
Testing of composites sensing properties



4% C-paste on reinforcing textile

Result:
- **Linear correlation of bending velocity and resistance velocity**

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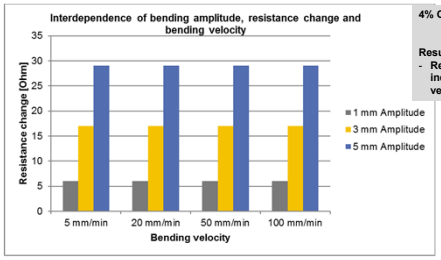
Testing of composites sensing properties



4% C-paste on reinforcing textile

Result:
- **Resistance change is independent from bending velocity**

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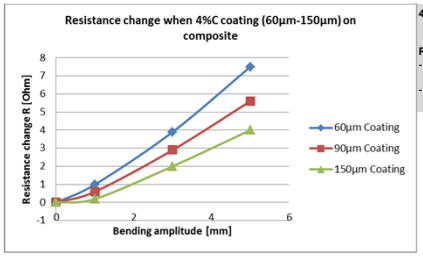
Testing of composites sensing properties (coating)



4%C coating on the composite

Result:
- **Resistance change depends on coating thickness and C%**
- **Largest resistance change at low C% and thin sensing coatings**

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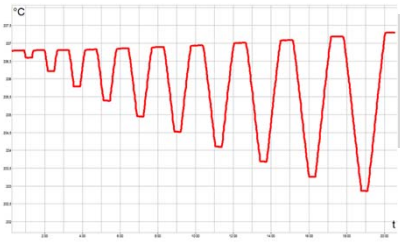
Testing of composites sensing properties (coating)



4%C , 150µm coating on the composite; Increasing amplitude Start 1mm, +0.5mm/cycle; 5 mm/min, 20sec stop

Result:
- **Resistance change correlates linear with amplitude**
- **No hysteresis**

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Conclusion

- **Large area strain gauge sensor on reinforcing textile was developed**
- **Resistance change correlates with bending amplitude**
- **Resistance change depends on C% in printing paste; low c% results in high resistance change**
- **No hysteresis even at high bending velocity**
- **No influence of bending velocity on resistance change**
- **Large area strain gauge sensors were also realized by means of coating on the composite**
- **Resistance change depends on coating thickness and C%; largest resistance change at low C% and thin sensing coatings**

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