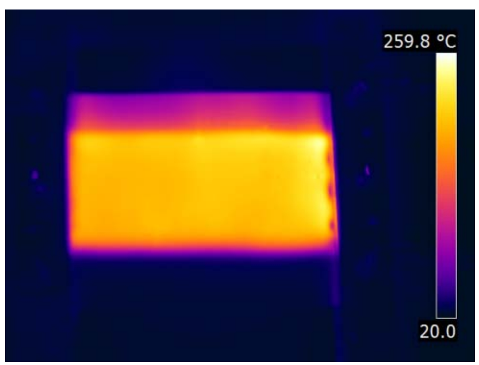
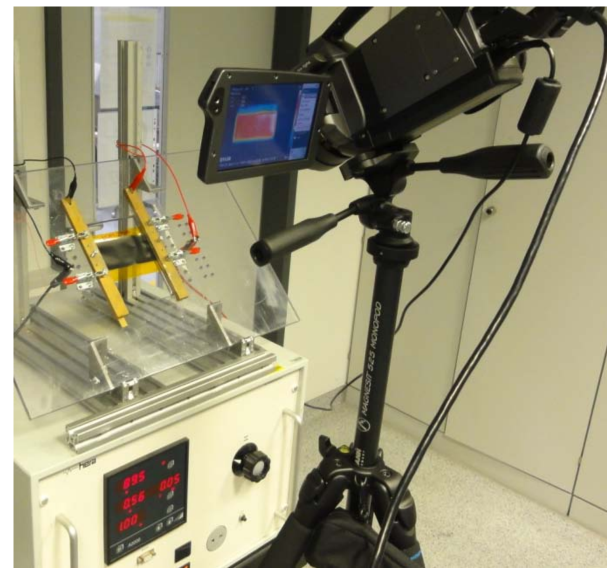
Stuttgart Nanodays 2011 Conference
September 29th and 30th, 2011
Ludwigsburg, Musikhalle

High-Performance Heating Elements

CNT Films on Thin and Flexible Substrates





Dominik Nemec

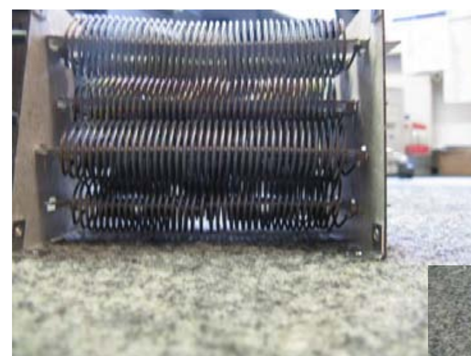
Fraunhofer IPA

Overview

- collaboration between applied research and industry
- how runs such a project
- ideas
- reality
- project → it is always a compromise

Why a new type of heating elements?

- Motivation/benefits
  - industrial partner → need for innovation
  - saving production costs → building-up a own production
  - less metal and simple building → saving of space and weight
  - energy saving
  - environmental protection



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Requirements and specifications

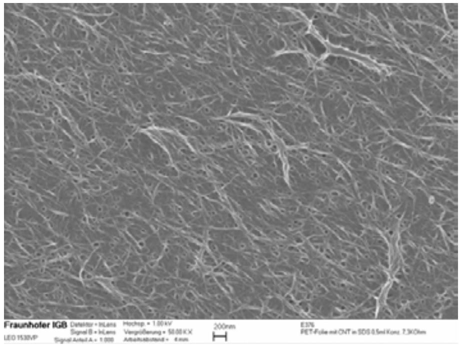
- thin film/coating
- low heat capacity
- homogeneous heat distribution
- substrates – mica (unique electrical and thermal insulating properties, low cost for mass production)

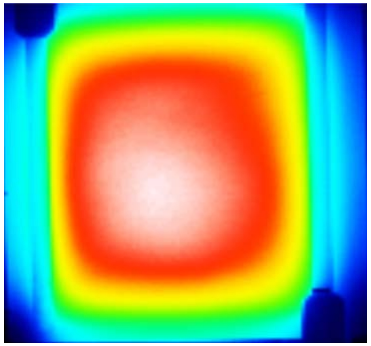
- power supply – 230 V
- operating temperature – 100 to 150 °C
- short-term temperature stress – 250 °C

Dispersion and film production

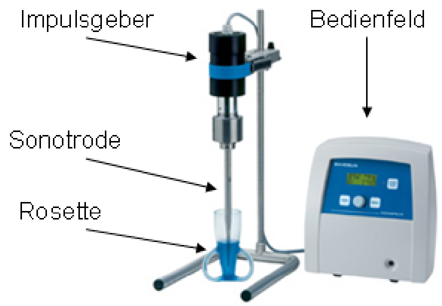
- part of Fraunhofer IPA:
  - development of CNT dispersion
  - production of thin CNT films
  - adhesion properties on substrate
  - electrical and thermal properties



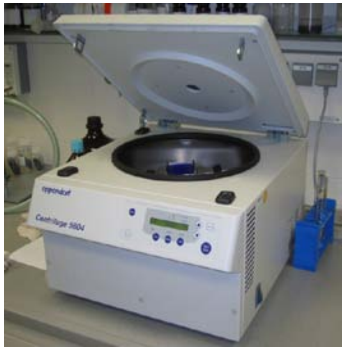




Dispersion

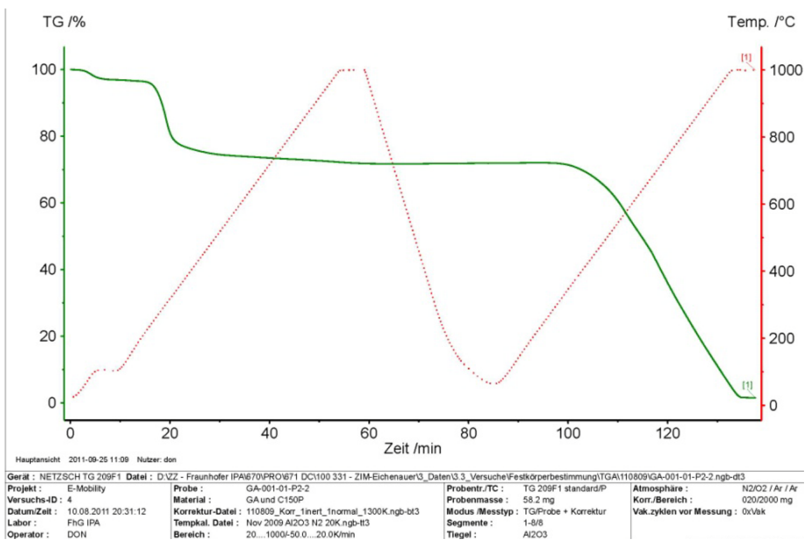


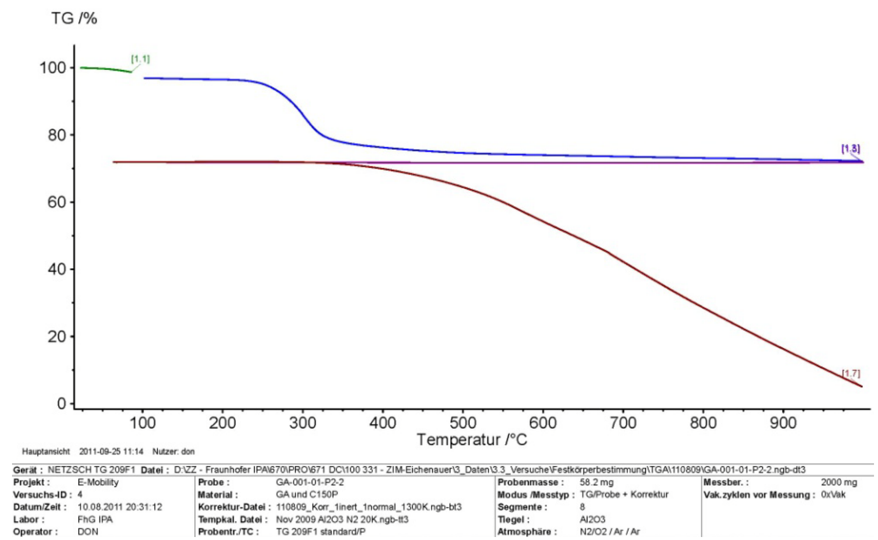
- carbon nanotubes (CNTs) → C150P (Baytubes)
- water based dispersion
- additives
  - gum Arabicum as dispersant
  - ethanol to minimize the surface tension
- dispersion quality → quantity, distribution and particle size of CNTs in the dispersion



CNT dispersion

- incorporation of CNTs in the dispersion

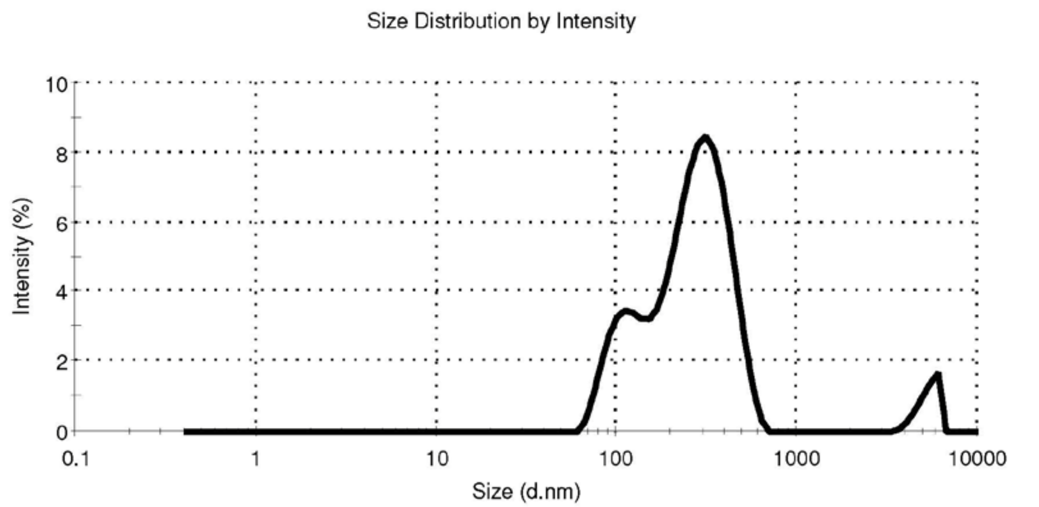




CNT dispersion

- particle size and distribution

			Diam. (nm)	% Intensity	Width (nm)
Z-Average (d.nm):	220	Peak 1:	305	73.3	101
PdI:	0.362	Peak 2:	113	21.9	23.8
Intercept:	0.870	Peak 3:	5290	4.8	652



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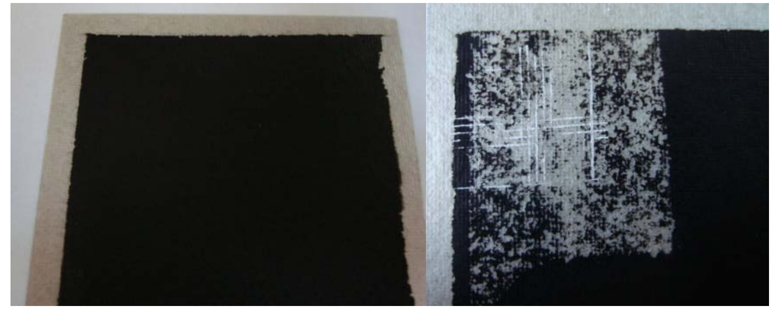
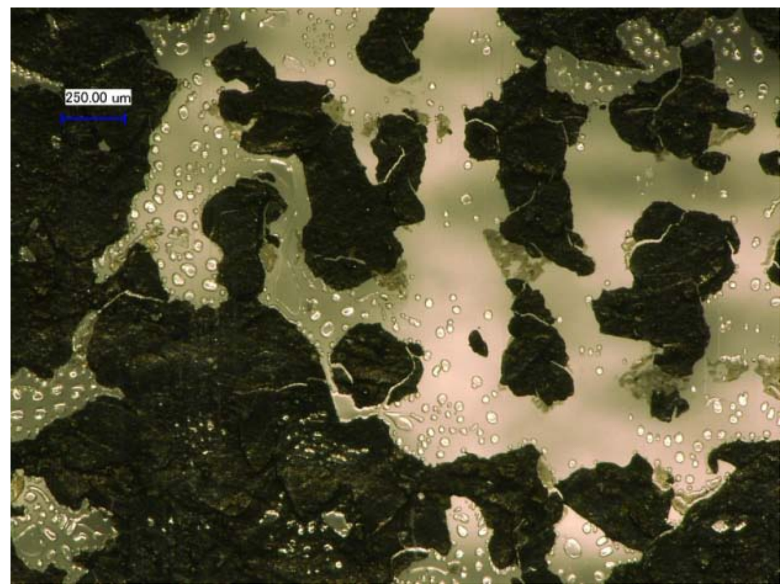
Substrates

- mica (mica plates)
  - electrically insulating
  - stable for thermal and heating capacity up to 350 °C or 3,5 W/cm²
  - low cost for mass production
- CNT film production
  - spray coating
  - good wetting of the surface
  - low adhesion → exfoliation of the mica sheets





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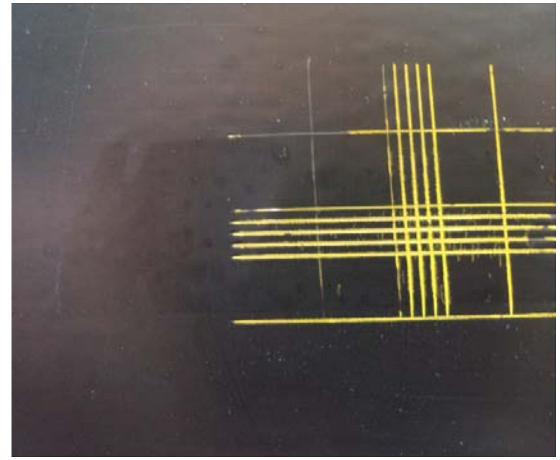
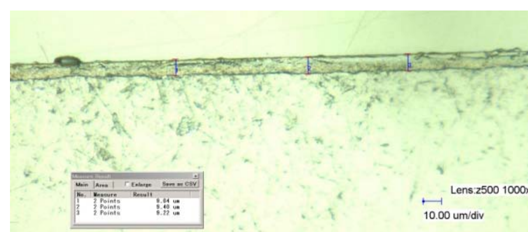
Substrates

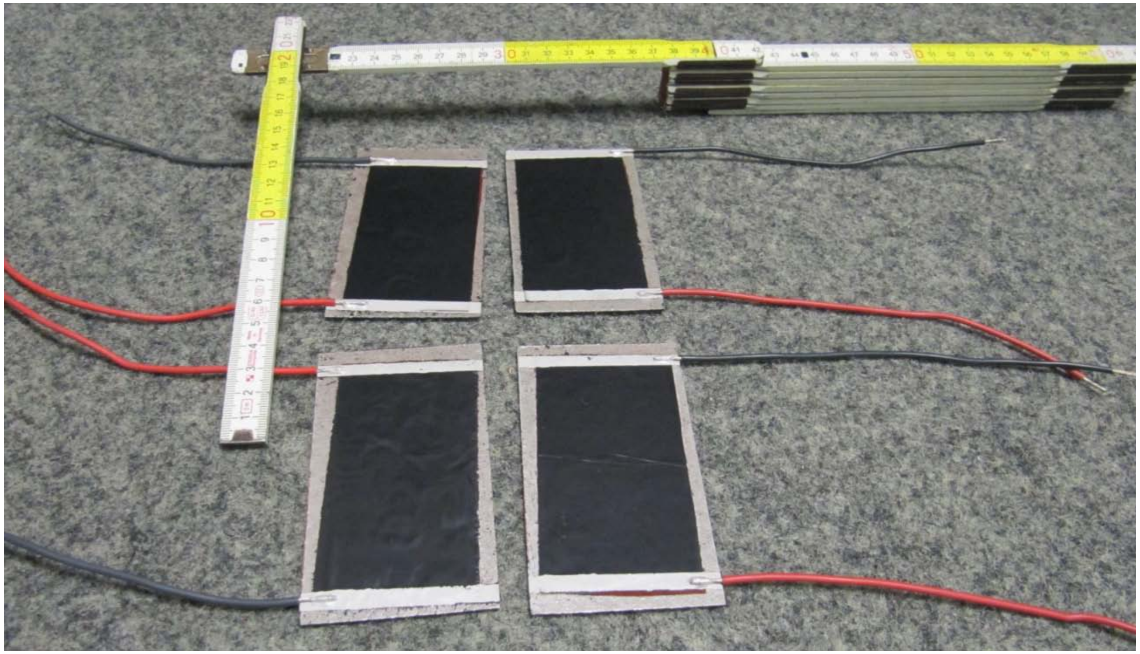
- polyimide film (kapton - developed by DuPont)
  - electrically insulating
  - thermal stable up to 400 °C
  - flexible
- CNT film production
  - spray coating
  - good wetting of the surface
  - very good adhesion
  - coating thickness – 9 to 10 µm
  - sheet resistance ~ 40 Ω/sq

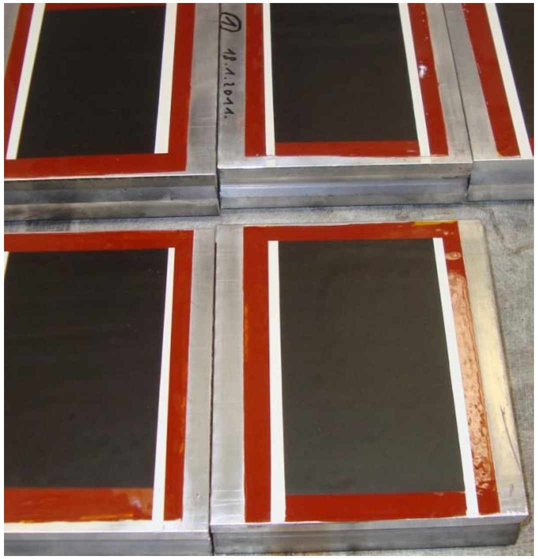




Experiments and results

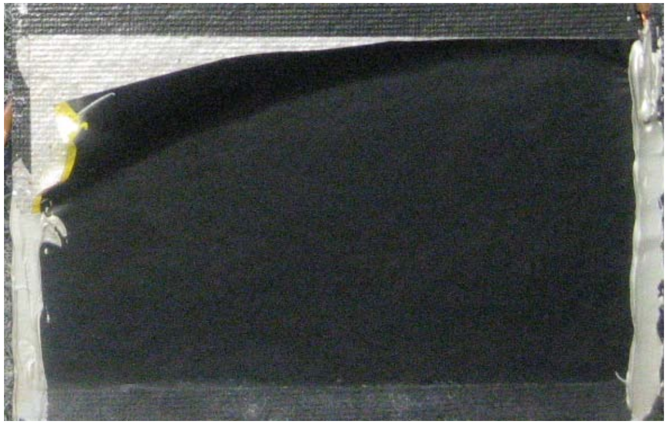
- polyimide film on mica and aluminum plates

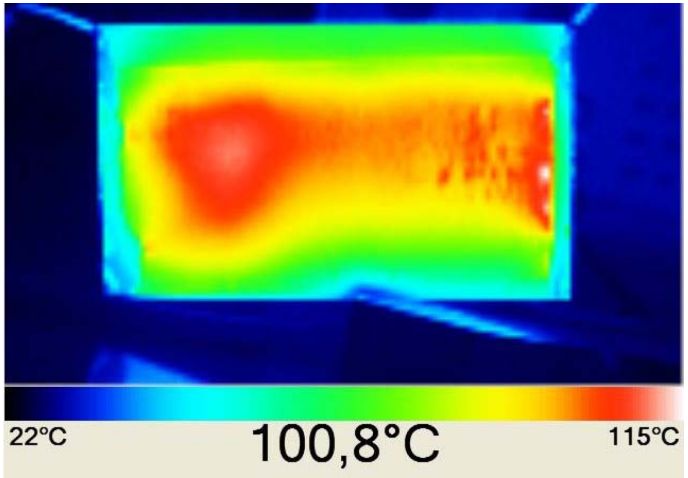




Experiments and results

- for the first coating tests – polyimide film was applied on mica and aluminum plates
- non-homogeneous temperature/heat distribution
- low adhesion of polyimide film to mica plate → adhesive is not temperature stable





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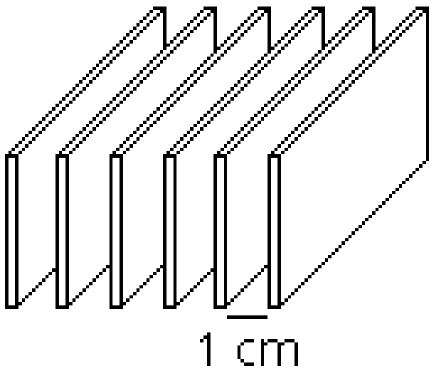
Experiments and results

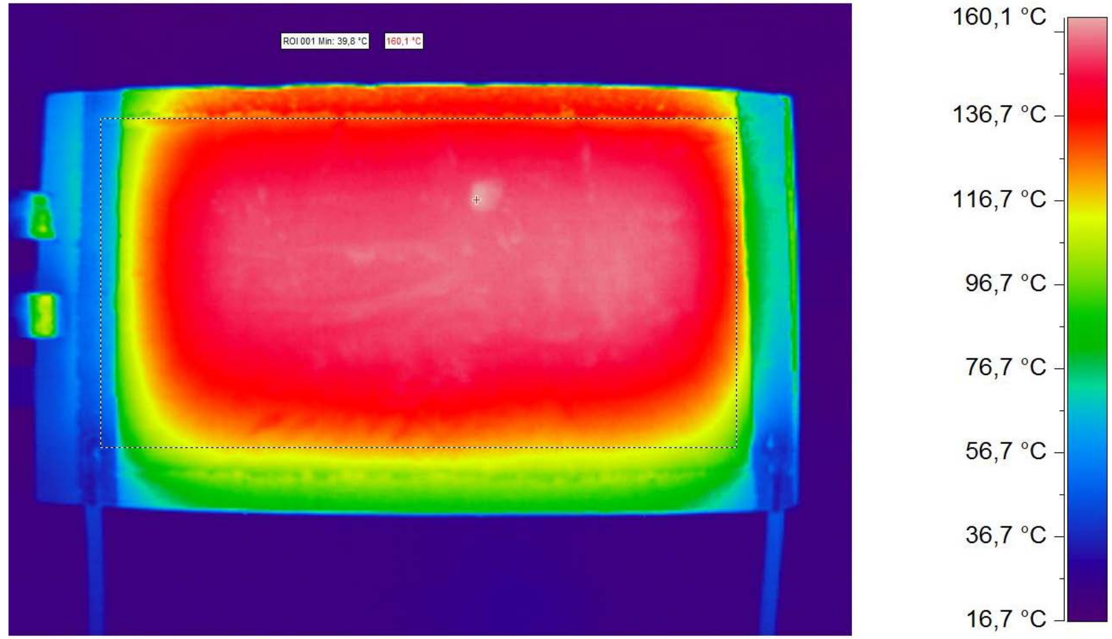
- dimension of the samples 50 x 100 mm²
- power supply – 35 V
- ambient temperature
- cooled with fan



number of cycles	heating	cooling	temperature
0 to 3385	1 min	12 s	ca. 90°C
3386 to 7691	2 min	12 s	ca. 100°C
7692 to13167	3 min	18 s	ca. 110°C

Experiments and results

- lifetime tests → up to 13000 cycles
- acceptable resistance change
- homogeneous temperature/heat distribution



sample number	cold resistivity	after 3385 cycles	change from the beginning	after 7691 cycles	change from the beginning	after 13167 cycles	change from the beginning
6	92 Ohm	87 Ohm	-5,40%	87 Ohm	-5,40%	-	-
10	103 Ohm	100 Ohm	-2,90%	100 Ohm	-2,90%	99 Ohm	-3,90%
11	107 Ohm	104 Ohm	-2,80%	104 Ohm	-2,80%	-	-
12	110 Ohm	105 Ohm	-4,50%	105 Ohm	-4,50%	107 Ohm	-2,70%
17	91 Ohm	90 Ohm	-1,10%	90 Ohm	-1,10%	90 Ohm	-1,10%
18	84 Ohm	80 Ohm	-4,80%	81 Ohm	-3,60%	92 Ohm	9,50%

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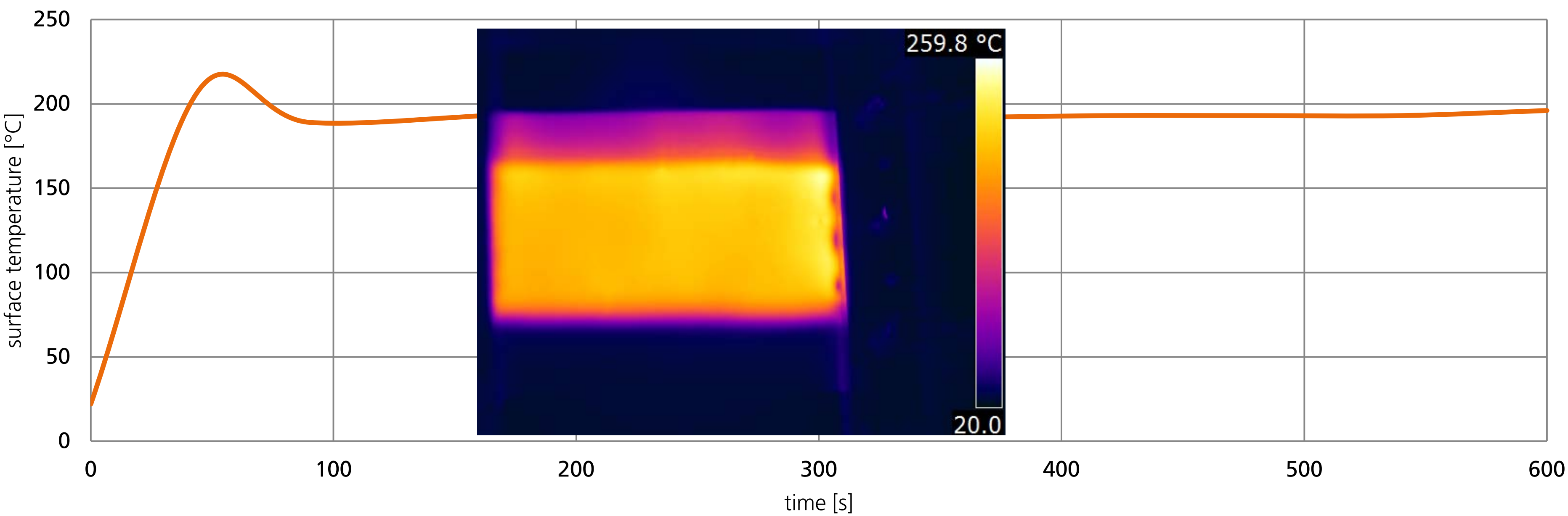
Experiments and results

- dimension of the sample – 108 x 48 mm²

heating element - CNT coating on polyimide foil - 90 V (~1 W/cm²)



Experiments

- CNT film on mica plate in air and oil

Experiments

- CNT film on polyimide, glued on mica plate, in oil
- dimension of the sample – 100 x 50 mm²
- 300 V; 4,7 A

  → 1400 W

  → 28 W/cm²

Outlook

- insulating
  → electrically for voltage > 48 V
  → oxidation of the CNT film for temperature > 250 °C
- contacting of samples
- film thickness – controlled by spray coating
- reduce the electrical conductivity for 230 V
- concepts for mass production implemetation in the application

Acknowledgement

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Thank you for
your attention!

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