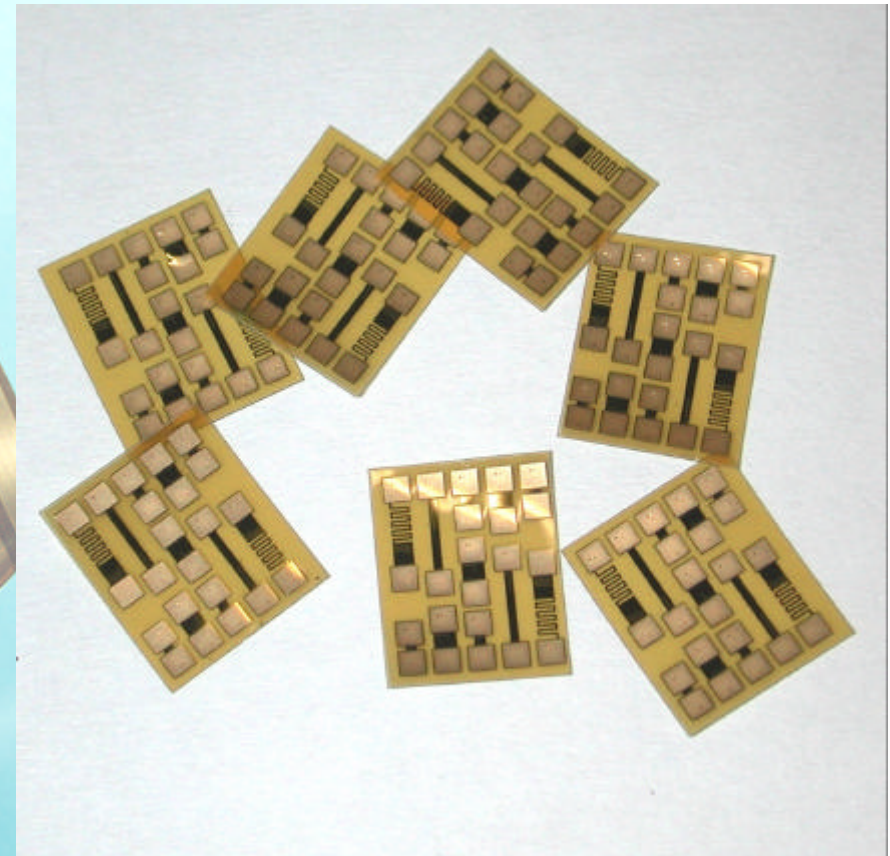


# ***Thin Film Resistor Integration into Flex-Boards***



7<sup>th</sup> International Workshop  
**‘Flexible Electronic Systems’**  
November 29, 2006, Munich

by

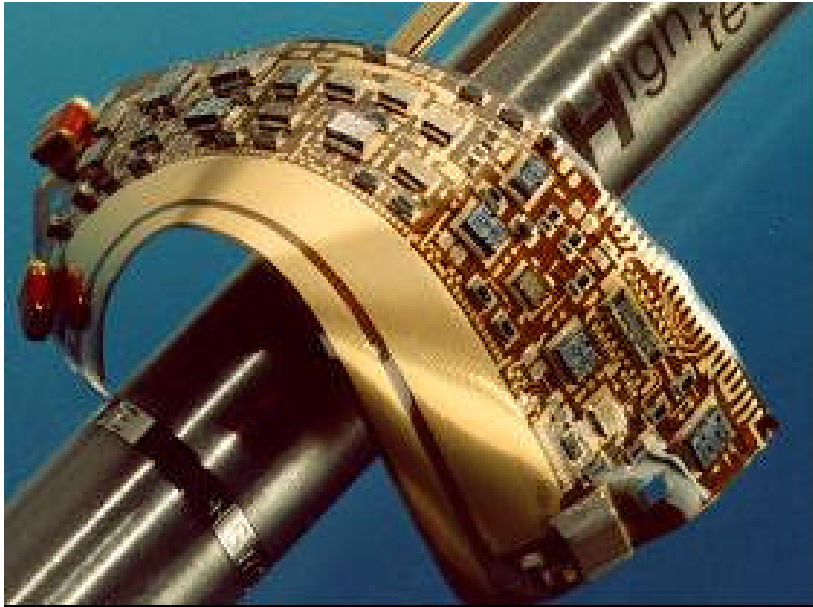
Dr. Hans Burkard  
Hightec MC AG, Lenzburg, Switzerland



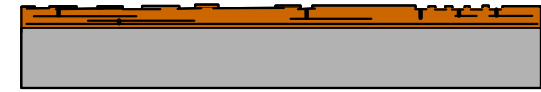
# Content

- **HiCoFlex: Process + Properties**
- Integrated NiCr Thin Film Resistors
  - Making
  - Characterisation and Testing
  - Properties
- Integration into PCB
- Conclusions + Future prospects

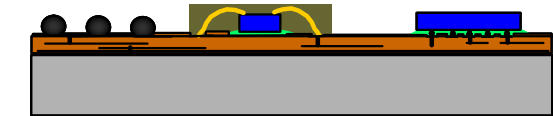
# HiCoFlex<sup>®</sup> Process



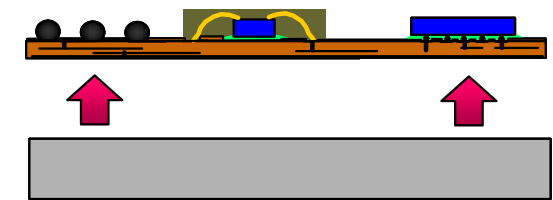
Fabrication of Multilayer  
Structure on  
Rigid Carrier Substrate



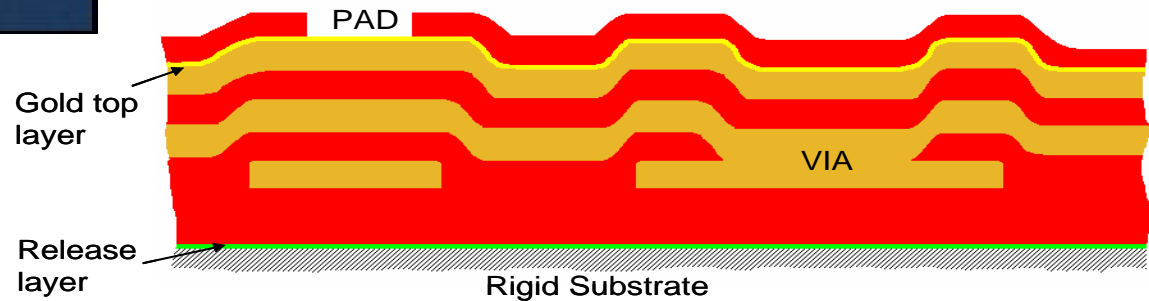
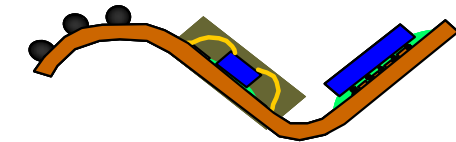
Assembling, Bonding,  
Protection, Test



Separation of Multilayer  
from Rigid Substrate  
Reuse of Carrier



HiCoFlex

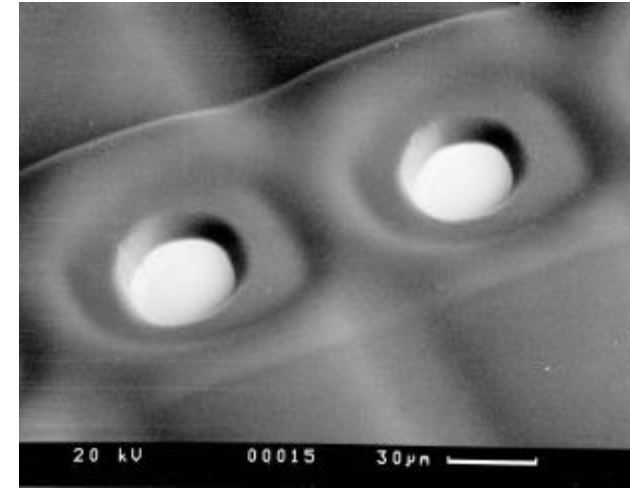


# HiCoFlex<sup>®</sup> Resolution and Vias

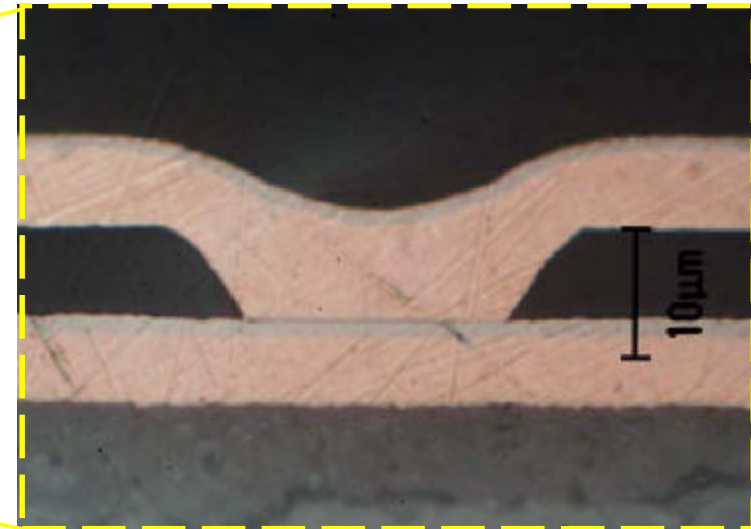
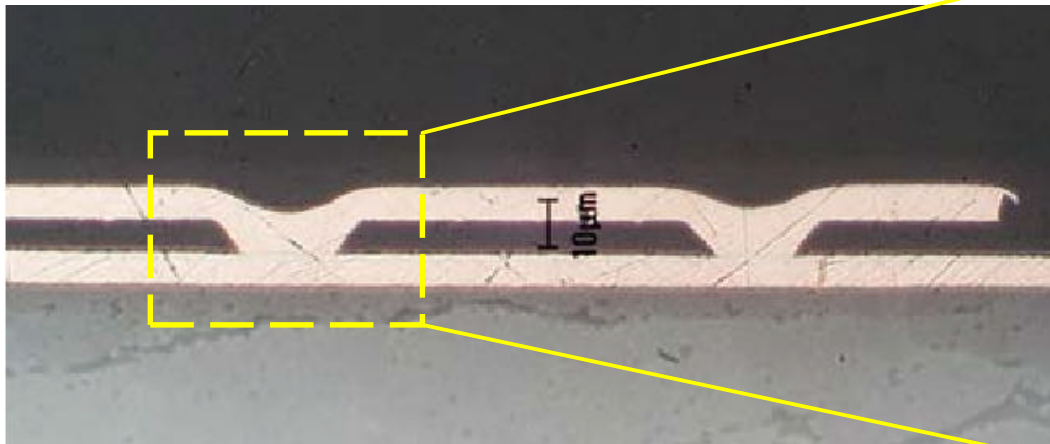


15 μm line / space  
conductors

Laser cut vias  
Ø 30 μm

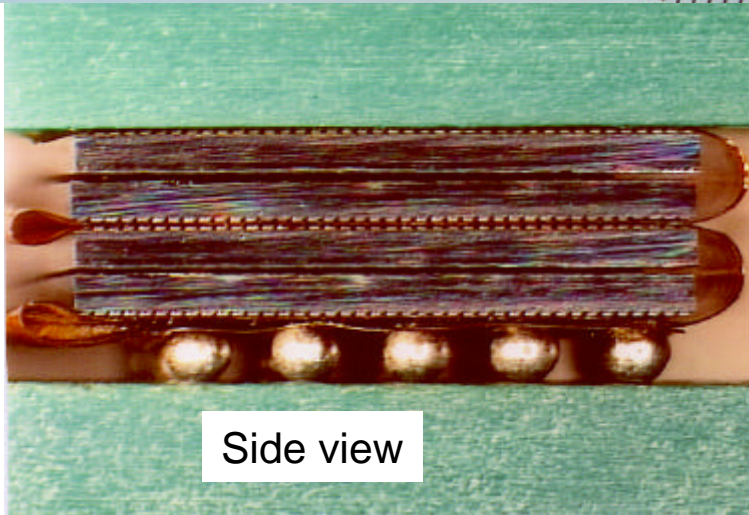
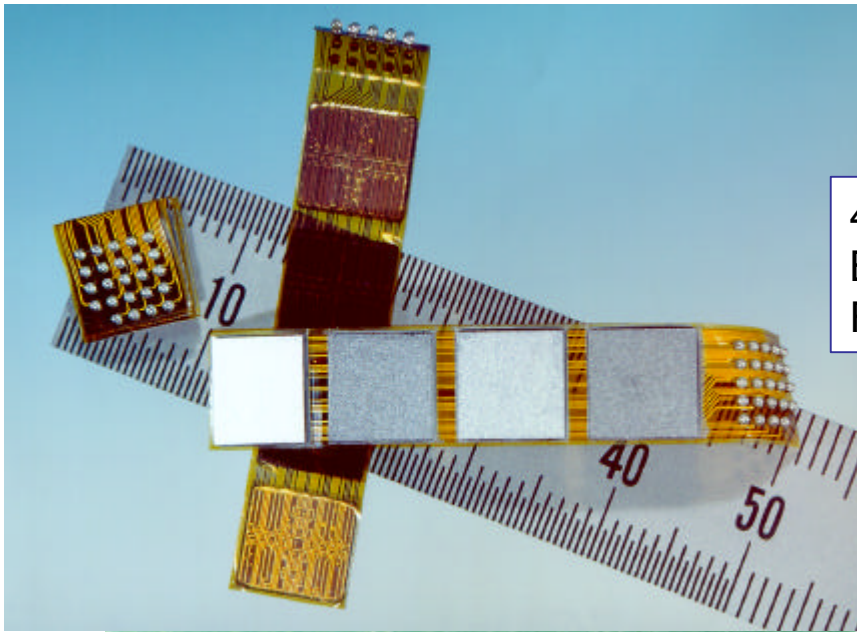


Electroplated vias

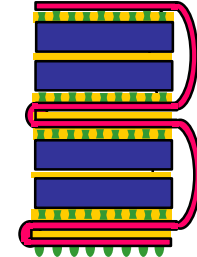
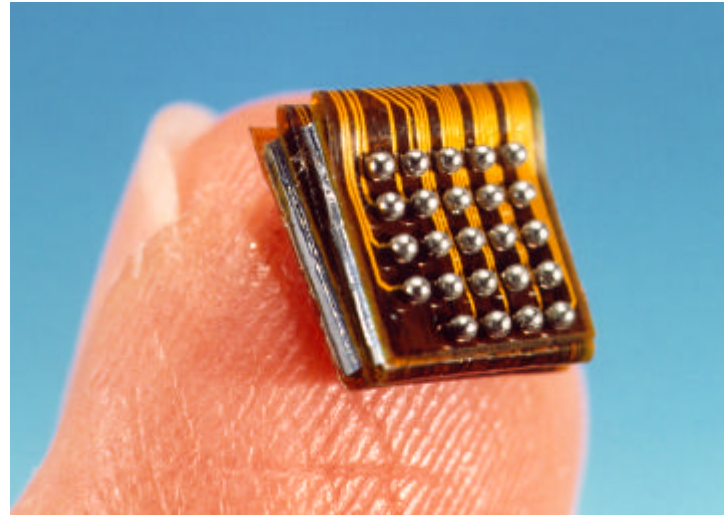


## HiCoFlex<sup>®</sup> 3D-Packaging

4 ICs, 7 x 7 mm, Flip-Chip on HiCoFlex  
BGA Pitch 1.27 mm  
Flip-Chip PbSn-Solder Interconnections Pitch 180  $\mu$ m



Side view



# Content

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## *Making NiCr Resistors in HiCoFlex*

### **Making of integrated resistors in HiCoFlex**

- Release layer
- Polyimide P0
- Sputter NiCr, lithography R
- Sputter Ti/Cu, lithography L1 and electroplate Cu/Ni
- Annealing (aging NiCr)
- Laser trimming
- Polyimide P1
- Laser drill vias
- Sputter Ti/Cu, lithography L2 and electroplate Cu/Ni
- ... further layers if needed ...
- Separation

# Making NiCr Resistor Foil Elements

separation layer

ceramics  
glass

polyimide

NiCr+Ti/Cu/Ni

polyimide

deposition of  
separation layer

resistors + contacts  
anneal + trim R's

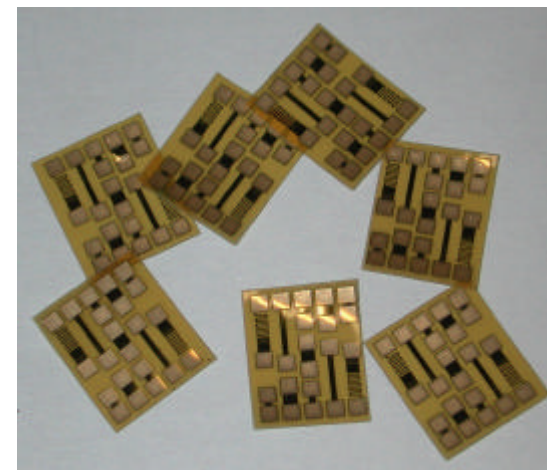
laser drilled vias

Ti/Cu

contact metal

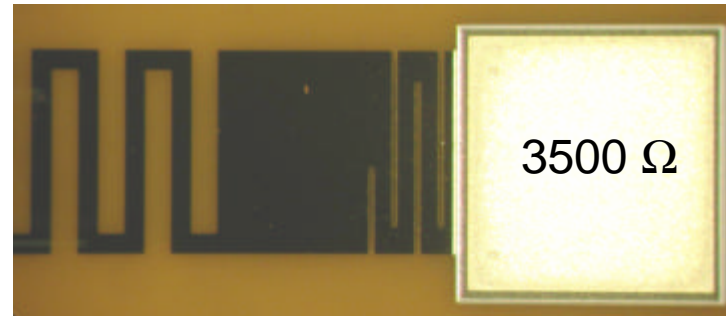
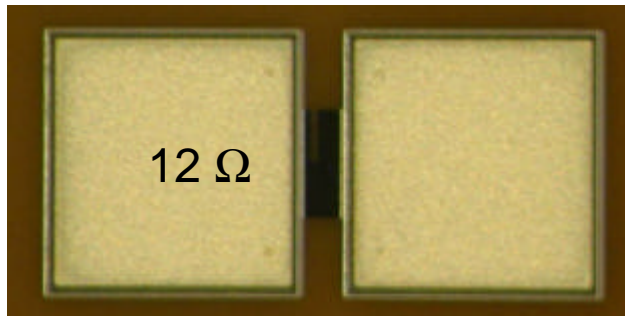
Separation  
force-free

foil elements

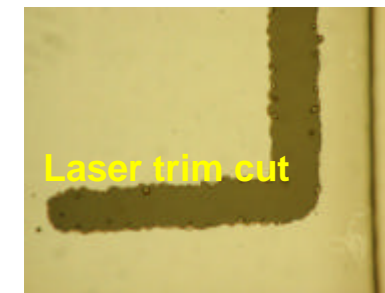
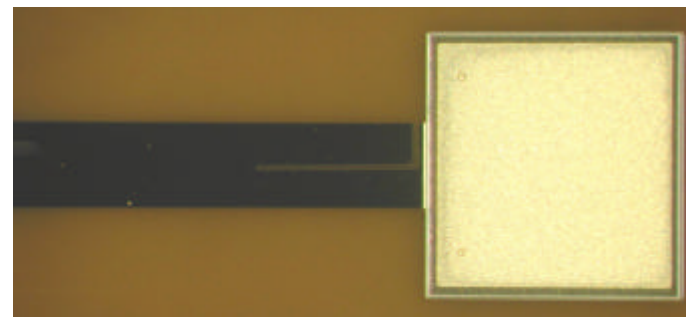
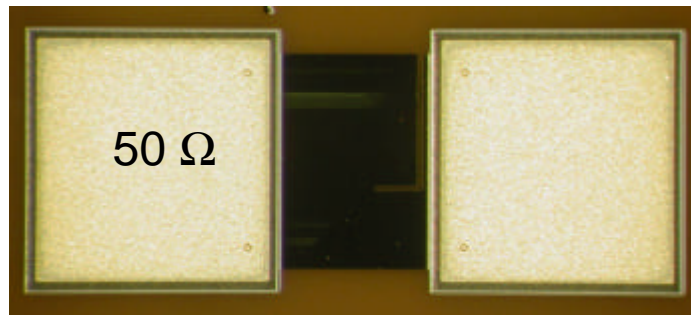
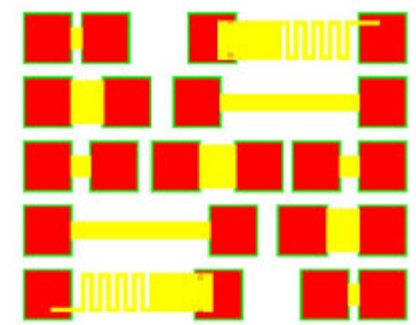
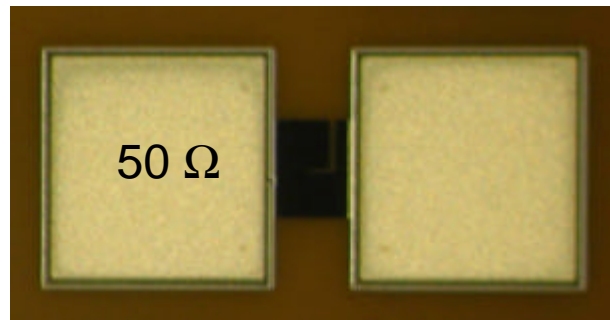




# Integrated NiCr Resistors in HiCoFlex



Test Layout  
Hi0550

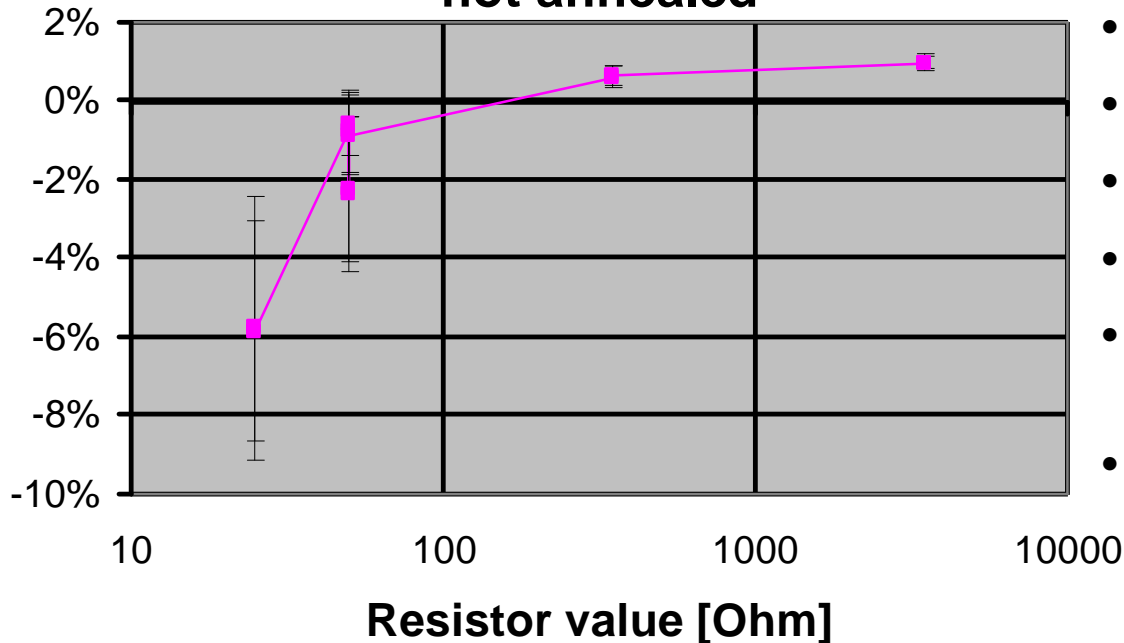


## *Tests and Characterisation*

- Measure resistance + Laser trimming
- Drift during PI curing (380°C peak temp)
- Measure TCR
- Temperature life test, 1000h, 125°C
- Humidity test, 1000h, 85% r.H. / 85°C, 18 VDC
- Bending test

# Resistor Drift during PI curing

**Drift of 50 Ohm/sq NiCr at P1 curing, not annealed**



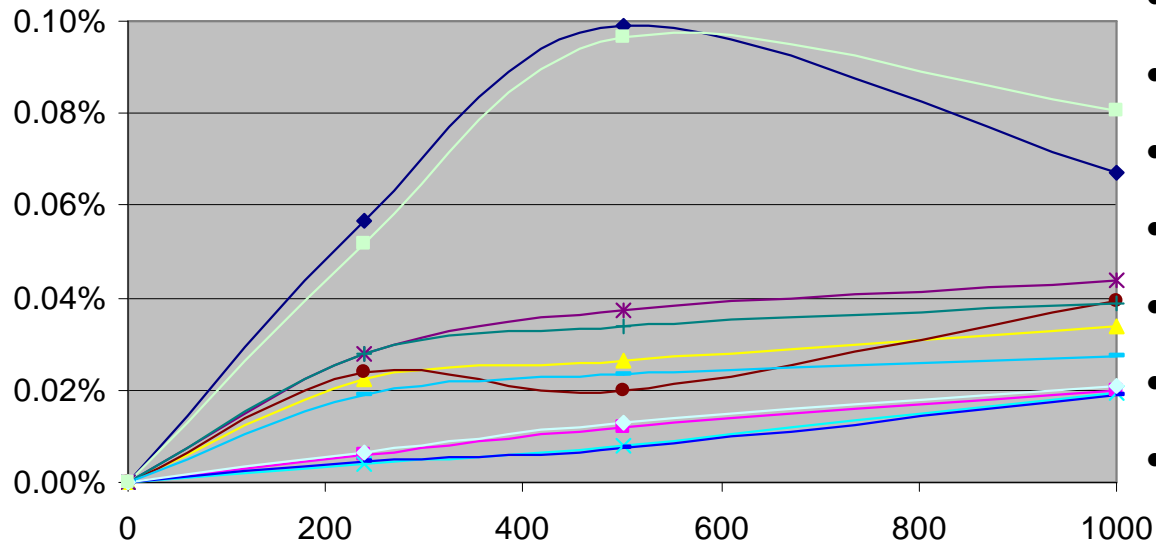
- Resistors not yet annealed
- 11 different R's, mean of 98 pcs each
- Curing at 380°C peak temperature
- Drift strongly depended on R values
- High R's: Low positive drift, only  $\cong 1\%$
- Low R's: High negative drift + large scattering.
- Influence of the metal contacts !

## TCR

-18 ± 8 ppm/°C, as on Al<sub>2</sub>O<sub>3</sub>

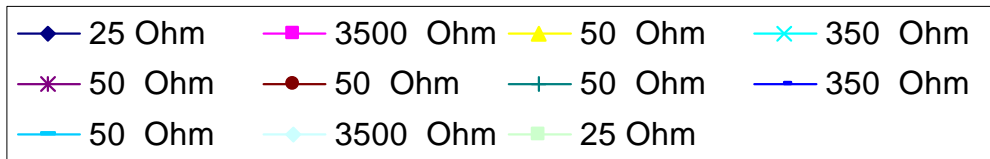
# Temperature Life Test

## Mean Abs. Drift Integrated Resistors



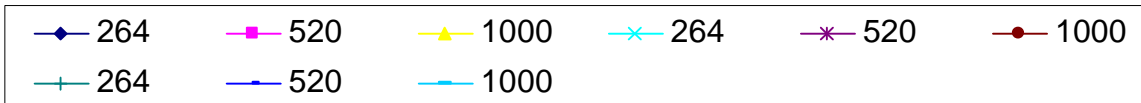
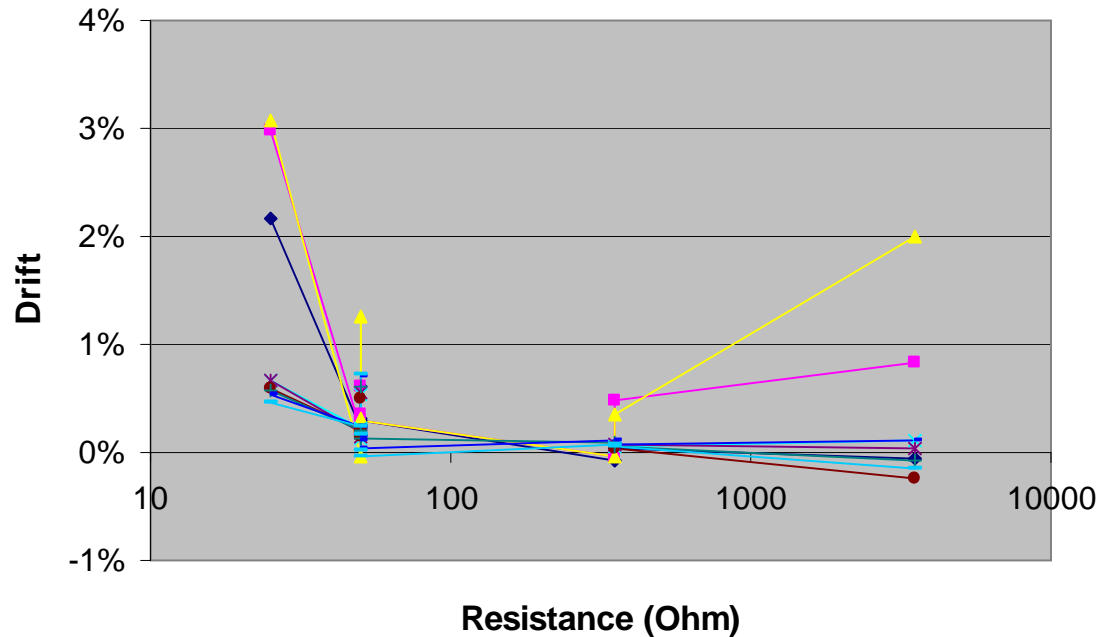
- Resistors annealed
- 11 different R's, mean of 54 pcs each
- Storage at 125°C
- Drift strongly depended on R values
- High R's: Low drift, typical < 0.05%
- Low R's: Higher drift
- Influence of the metal contacts !

**Time [h] at 125°C**



# Humidity Test

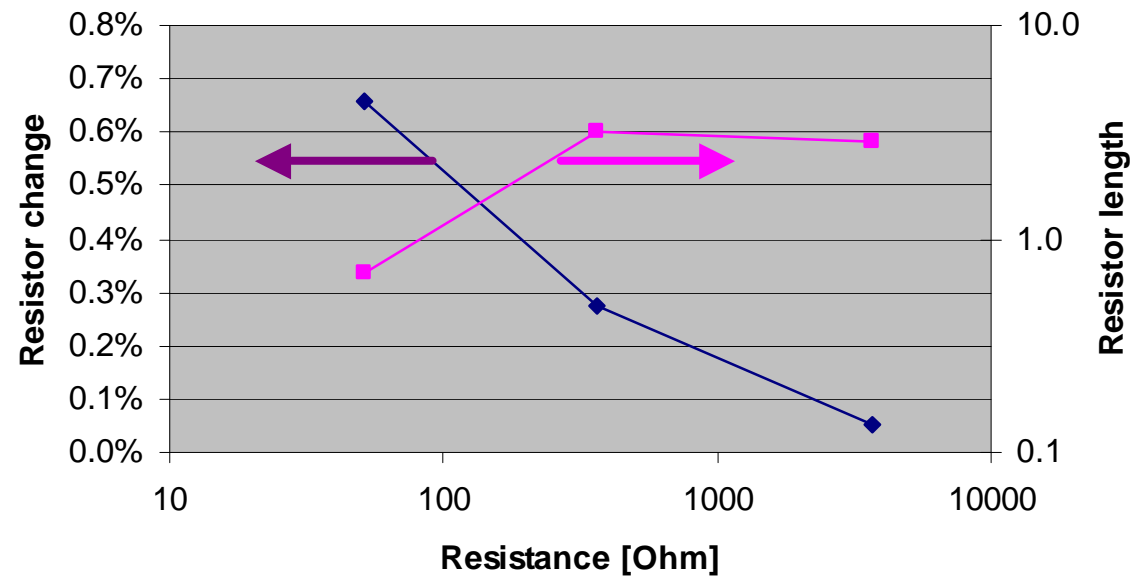
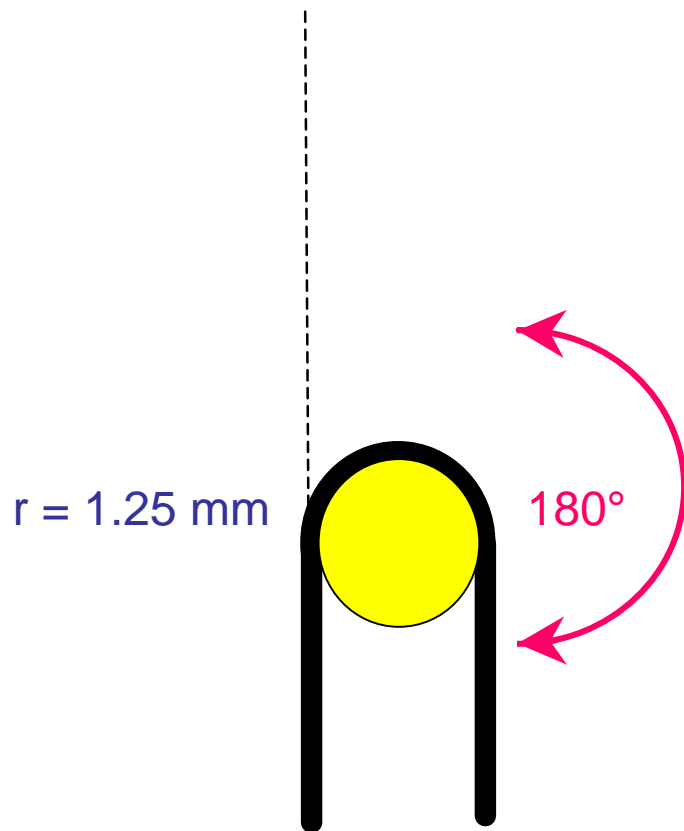
**Humidity Test / Sub1-Blocks 7-9 with 18 V**



- Resistors annealed
- 11 different R's, 3 pcs each
- Storage at 85% r.H. / 85°C
- 18 VDC applied
- Drift depended on R values
- Medium R's: Low drift, typical < 1%
- Low + high R's: Higher drift
- Without applied voltage: Similar results

# Bending Test

## Bending of Integrated Resistors



- Simple bending test:  $\Delta\text{Resistance} = R_{\text{bent}} - R_{\text{straight}}$  (reversible strain gauge effect)
- NiCr layer  $\cong$  at neutral line  $\Rightarrow$  Change comes from stretching of the foil
- 3 different R's measured
- Bending effect is small and somehow dependend on resistor length and value

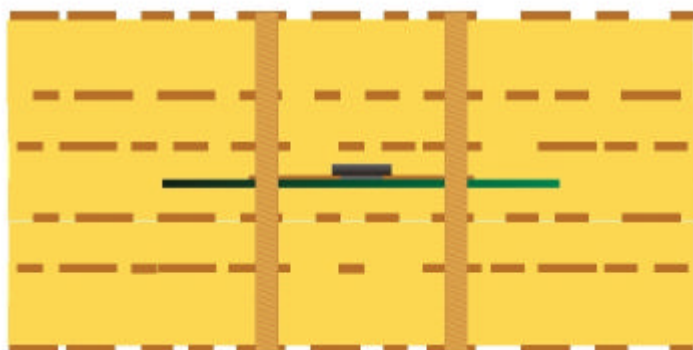
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## Integration into PCB

**SHIFT:** The project 'Lamination of foils with integrated or embedded components and connection to the wiring of the print' has been started, but is not finished.

PCB manufacturers have shown that the lamination of a flex foil into a flex or rigid board works. See e.g. **SEAG i Board**



In the centre → contacting by through holes



Near surface → contacting by laser drilled vias

**SEAG i Board**



pictures by courtesy of SEAG



# Content

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## *Future prospects + Conclusions*

### **Conclusions for NiCr thin film resistors**

- ✓ can be integrated into HiCoFlex
- ✓ can be laser trimmed
- ✓ Range: 10  $\Omega$  - 100 k  $\Omega$
- ✓ TCR:  $-18 \pm 8$  ppm/ $^{\circ}\text{C}$ , same as on  $\text{Al}_2\text{O}_3$
- ✓ Stability at 125 $^{\circ}\text{C}$  1000h: Drift < 0.1% are very stable
- ✓ Humidity tests, 18 VDC, 1000h, typ < 1%
- ✓ Bending tests, radius = 1 mm, typ < 1%
- ✓ Integration into flexible PCB: first versions proven

Next steps and future prospects for 'Integration into rigid or flexible PCB':

Thin flexible foils with

- Resistors,
- RF structures,
- integrated capacitors and
- embedded chips (active components)

⇒ Limit the use of the expensive high resolution techniques to the areas where it is absolutely necessary