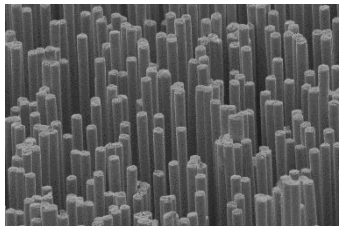
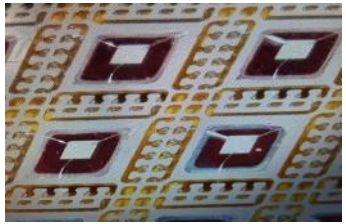
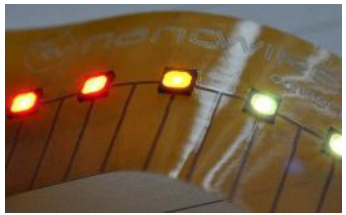
Frequently Asked Questions – Rev. 23

NanoWiring, KlettWelding, KlettSintering, KlettGlueing







nanoWiring nanoInspection KlettWelding KlettSintering KlettGlueing

Technology basics

1.00 Definitions

Q: What are the standard process definitions

1. NanoWiring: creates a metallic lawn on any surface
2. KlettWelding: realizes the connection of two substrates prepared with NanoWiring
3. KlettSintering: allows the connection with only one substrate prepared with NanoWiring
4. KlettGlueing: enables the contacting of fragile components using an adhesive
5. KlettWelding-Tape: even untreated substrates can be joined together.

Q: What does MPa mean

1 MPa = 1N/mm²

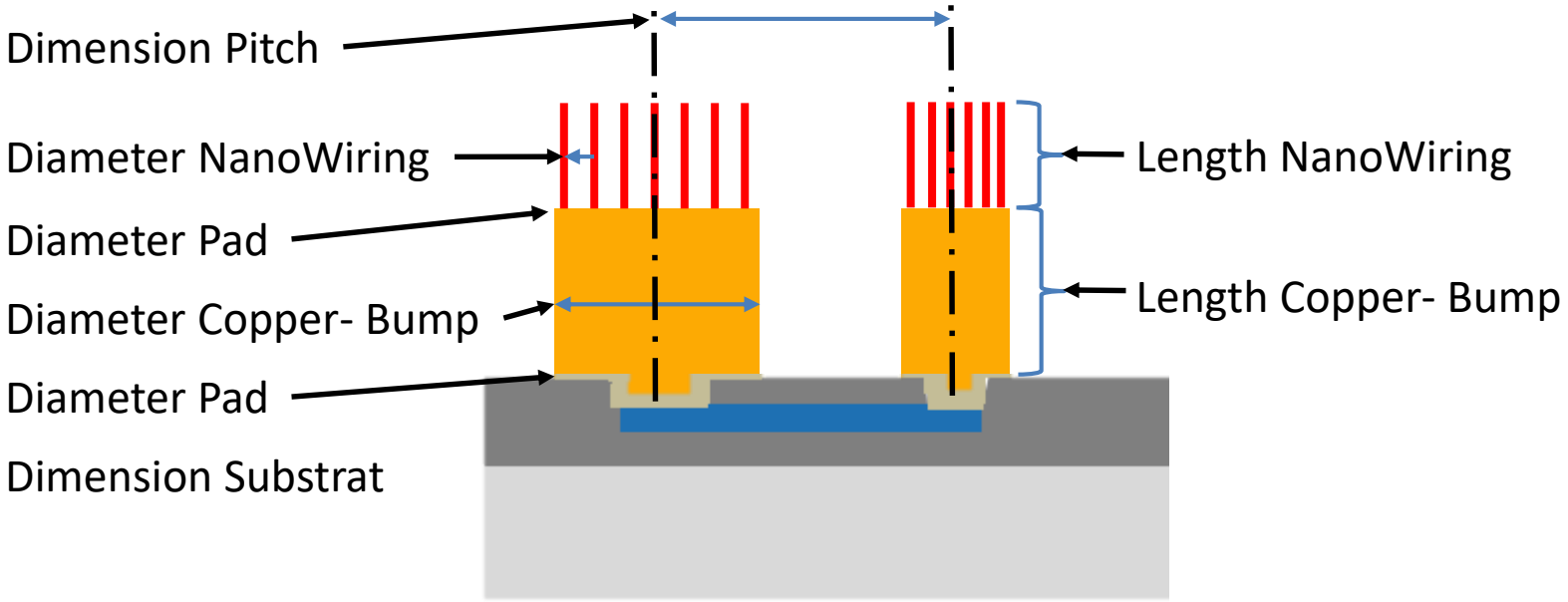
1 MPa = 100g/mm²

1 MPa = 10bar

Technology basics

1.00 Definitions

Q: Which dimension descriptions are used for bumps?

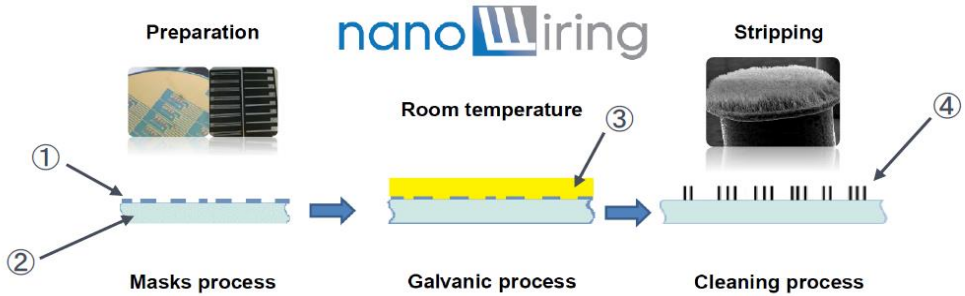


Technology basics

1.01 Consistent materials

Q: What are composition materials from 1 to 4 on drawing below?

1. Can be a photoresist (preferably positive) but can also be a rubber lip, Capton tape, solder stop lacquer, or any other type of cover to expose the areas to be coated with NanoWiring. The masking material depends on the tolerance to be achieved.
2. The substrate material can be any material such as plastic, glass, ceramics, steel, aluminium, semiconductor material, copper, brass, etc. as long as there is an adhesion and a seed layer that can be manufactured industrially.
3. This is a special sponge with a special porosity layer. The porosity layer is filled with metal during the galvanic process.
4. The materials currently used are copper, silver, gold, nickel, zinc, platinum, ...



Technology basics

1.01 Consistent materials

Q: What is the material on special sponge to use for making NanoWiring? Is this metal or organic substance?

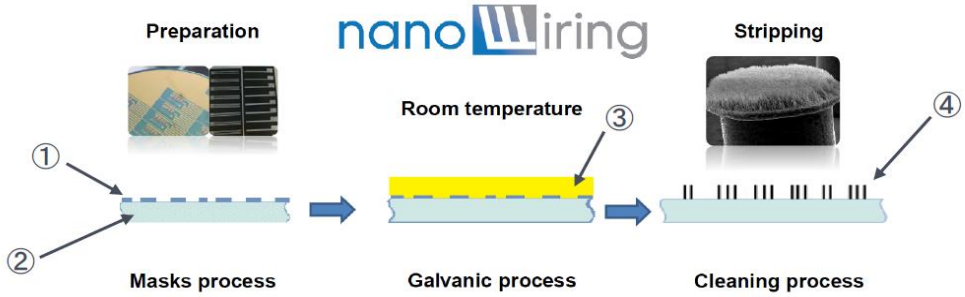
- The sponge with its porosity layer consists out of an organic material

Q: How do you put special sponge which has hole of µ-level into base material? Or do you put this special sponge into base material first and then you produce hole of µ-level?

- The porosity layer of the sponge is created by a special process.

Q: Do you wash away this sponge in Stripping process? Or do you have any other process to remove Sponge from substrates?

- To reduce the effort we remove a part of the sponge material mechanically, except for the area of the porosity layer. The area of the porosity layer is then removed wet-chemically using cyclopentanone. This is done in an automated multi-stage washing process, so that it is removed without residue.



Technology basics

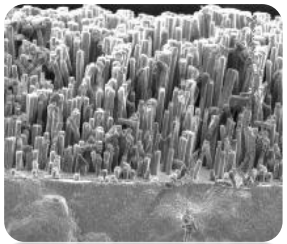
1.02 NanoWires geometry

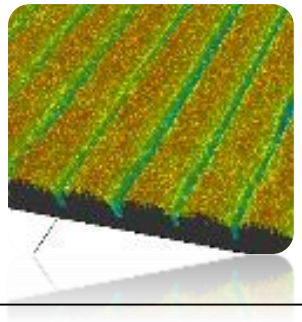
Q: What are the target values (diameter and length) of NanoWires?

- The diameter of the NanoWires can be adjusted between 30nm and 4µm.
- The length of the NanoWires can be created between 1µm and 50µm.

Q: How do you control the values such as diameter and length of NanoWires?

- The diameter and base length of the NanoWiring structure is defined by the porosity layer of the sponge material and is industrially guaranteed.
- The NanoWiring structure can be measured by SEM or confocal microscopy. For this purpose, there are established devices on the market which are also used for measuring the layer thickness on wafers.
- A stereo microscope is also sufficient to monitor the surface of the NanoWiring structure for contamination, scratches, defects or inhomogeneities.





Technology basics

1.03 Processing

Q: What kinds of processing equipment do you use?

1. *Lithography:*
   - For masking or passivating sensitive surfaces we use different established processes. Spray-coating, laminating lacquer, adhesive tape (Capton), mechanical covers, solder resist lacquer. Furthermore we use laser exposer or mask exposer.
2. *NanoWiring:*
   - For NanoWiring, we use our semi-automatic network-based NanoWiring production plant. This is a batch machine with a current production area of 300x300 mm². A drawer is inserted into the machine, which then provides appropriate devices for contacting, holding and covering the substrates. NanoWiring is a current-carrying process, it is an active galvanic process. The current deflection defines where the NanoWiring should take place.
3. *Stripping:*
   - We currently use a bath based system that passes the substrates through various solvents and cleaning agents to remove anything that is not needed for contact. Adhesion and seed layer are also removed here. We dry the substrates by air flow in the stripping plant.
4. *KlettWelding, KettSintering, KlettGlueing:*
   - For connecting the substrates turn with small components standard pick and place machines used. Standard placement machines have a placement force of approx. 8kg with a KlettWelding Force of 17MPa, which corresponds to a maximum contact area of 4.7mm². For higher forces, presses such as sinter presses of all kinds can be used. In this case it is important to ensure that the joining is plane-parallel.
5. *NanoInspection:*
   - Either stereo microscope, SEM, monochromatic microscopy, EDX

Technology basics

1.03 Processing

Q: What pretreatment is necessary for which substrate material for the different joining methods?

Substrate Material	NanoWiring / KlettWelding	KlettSintering
Ceramics (Al_2O_3)	• Sputtering Metallic Seedlayer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc) • Evaporation deposition of Ti/Pt/Au-Layer • Printing and burning Silver Paste	• Sputtering Metallic Layer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc). The metallic layer needs to be heat resitant. • Evaporation deposition of Ti/Pt/Au-Layer • Printing and burning Silver Paste The Layer must be heat resistant for KlettSintering.
Silicon	• Sputtering Metallic Seedlayer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc) • Evaporation deposition of Ti/Pt/Au-Layer	• Sputtering Metallic Seedlayer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc) • Evaporation deposition of Ti/Pt/Au-Layer The Layer must be heat resistant for KlettSintering.
Stainless Steel	1. Precoating with Gold-Flash 2. Optional: Pre Coating with Copper Electrodeposition	1. Precoating with Gold-Flash 2. Pre Coating with Copper Electrodeposition
Aluminium	1. Precoating with Zincate-Process 2. Precoating with Copper	1. Precoating with Zincate-Process 2. Precoating with Copper

Technology basics

1.03 Processing

Q: What pretreatment is necessary for which substrate material for the different joining methods?

Substrate Material	NanoWiring / KlettWelding	KlettSintering
Nickel	1. Precoating with Immersion Gold of Flash Gold 2. Optional: Precoating with Copper	1. Chromeing with Immersion Gold of Flash Gold 2. Optional: Precoating with Copper • If Formic Aced is used not pretreatment is necessary
Chrome	1. Precoating with Immersion Gold of Flash Gold 2. Optional: Precoating with Copper	1. Precoating with Immersion Gold of Flash Gold 2. Precoating with Copper
Glas (Borofloat)	• Sputtering Metallic Seedlayer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc) Evaporation deposition of Ti/Pt/Au-Layer	• Sputtering Metallic Seedlayer (Ni/Au, Ni/Cu, TiW/Cu, Cr/Cu, etc) • Evaporation deposition of Ti/Pt/Au-Layer The Layer must be heat resistant for KlettSintering
Copper	No treatment necessary	No treatment necessary
Gold	No treatment necessary	No treatment necessary
Silver	No treatment necessary	No treatment necessary
Brass	No treatment necessary	No treatment necessary

Technology basics

1.03 Processing

Q: How long is the processing time?

- The process time for the NanoWiring is depending on the NanoWiring length. In the initial phase we assume 1 hour all in process time for a batch run. This time is then reduced to approx. 15-30 minutes in the course of further process optimizations.

Q: How much is treatment temperature?

- For our copper plating process we use a temperature above room temperature but below 50° C so that it can be ensured at all times that the outside temperature has no influence on the process parameters. Furthermore, the temperature is so low that there is no damage to the substrate materials.

Q: Do you use any machine for dry process

- We have integrated an air-drying unit in the stripping machine, so that after the chemical cleaning of the substrates the substrate is dried.

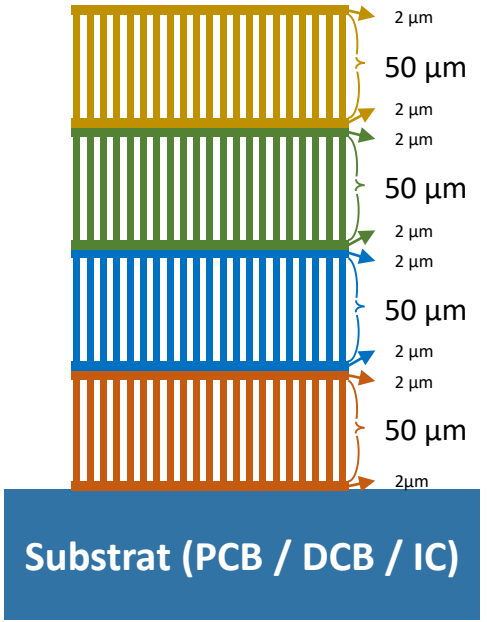
Technology basics

1.03 Processing

Q: What are the opportunities for large size substrates or wide variations?

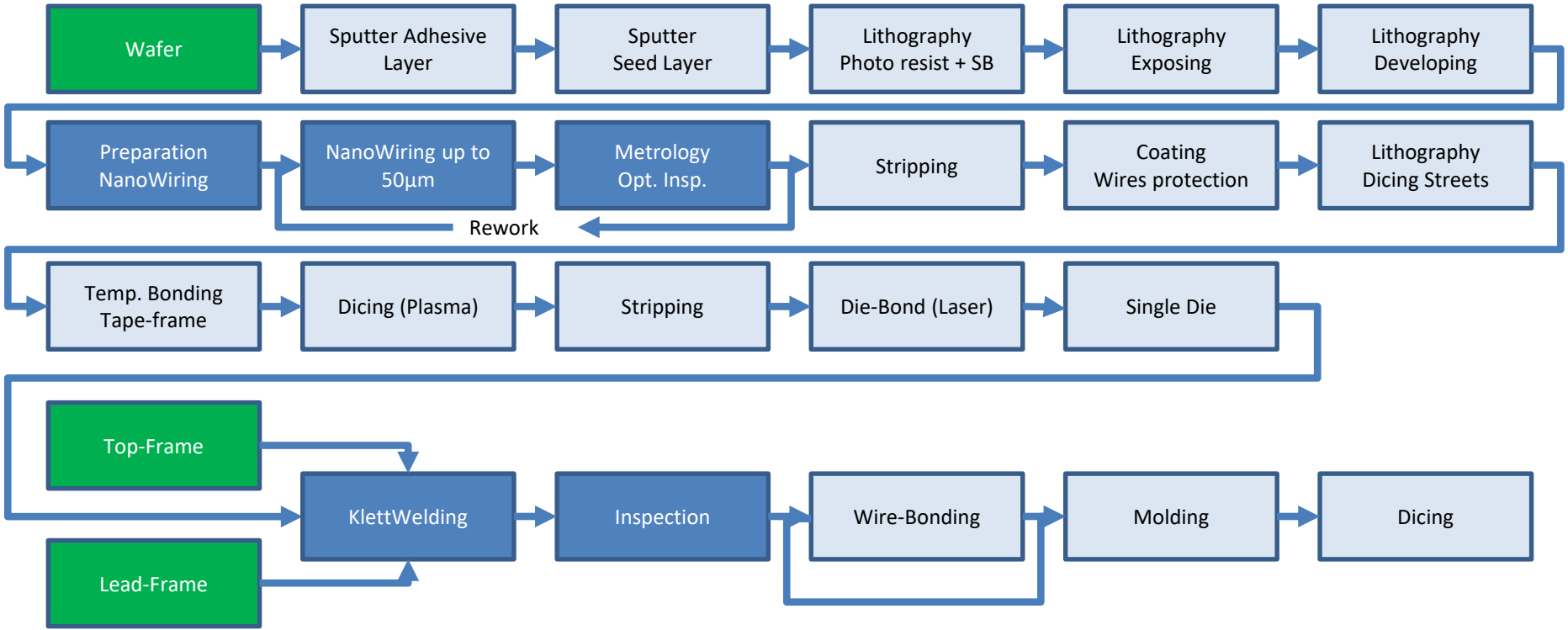
- To higher the bondline thickness or to have more flexibility inside the connection we can do a stilt NanoWiring. At the stilt NanoWiring process there are a multiple layers stacked over each other in multiple NanoWiring runs.
- Resulting bondline thickness:
  - $\mathbf{bondline\ thickness} = \mathbf{n_{Layer} * 55\ \mu m}$
- Example
  - 2 layers → bondline thickness = 110 µm
  - 4 layers → bondline thickness = 220 µm

Stilt-NanoWiring



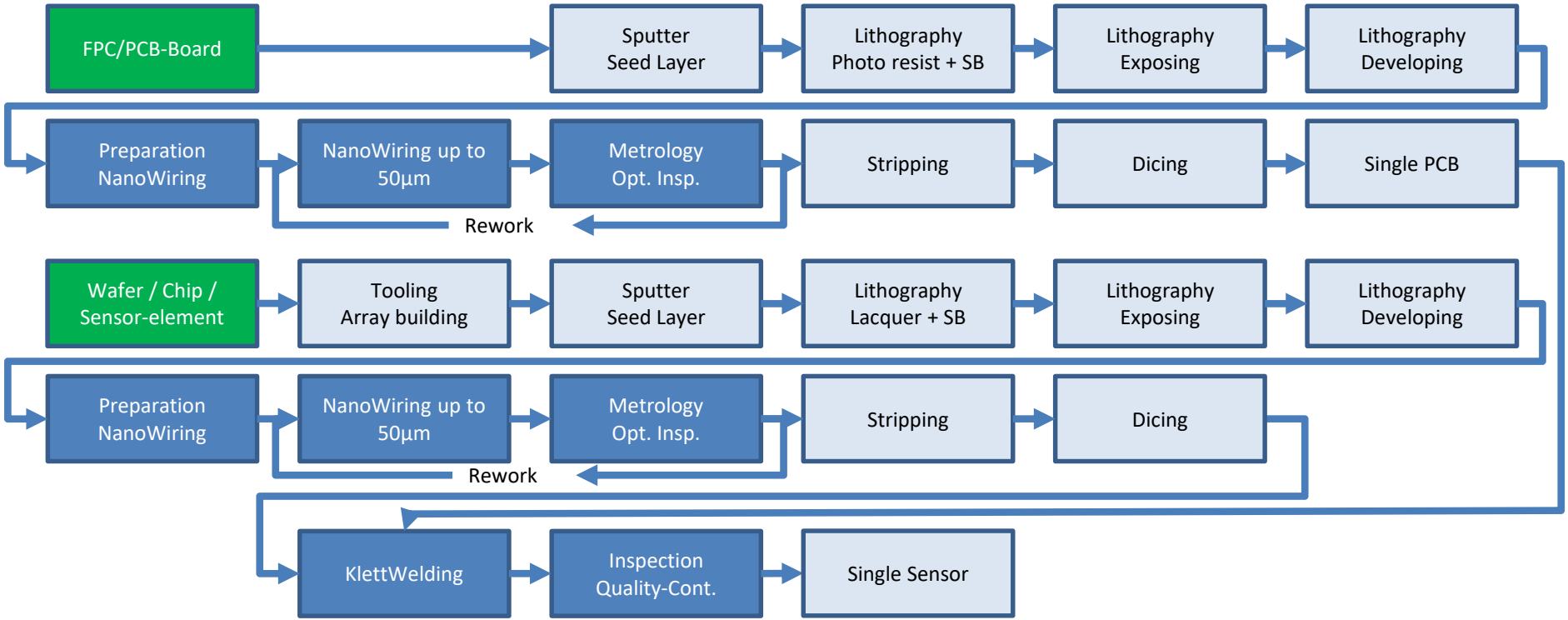
Technology basics

1.04 Process flow - Die / Lead-Frame



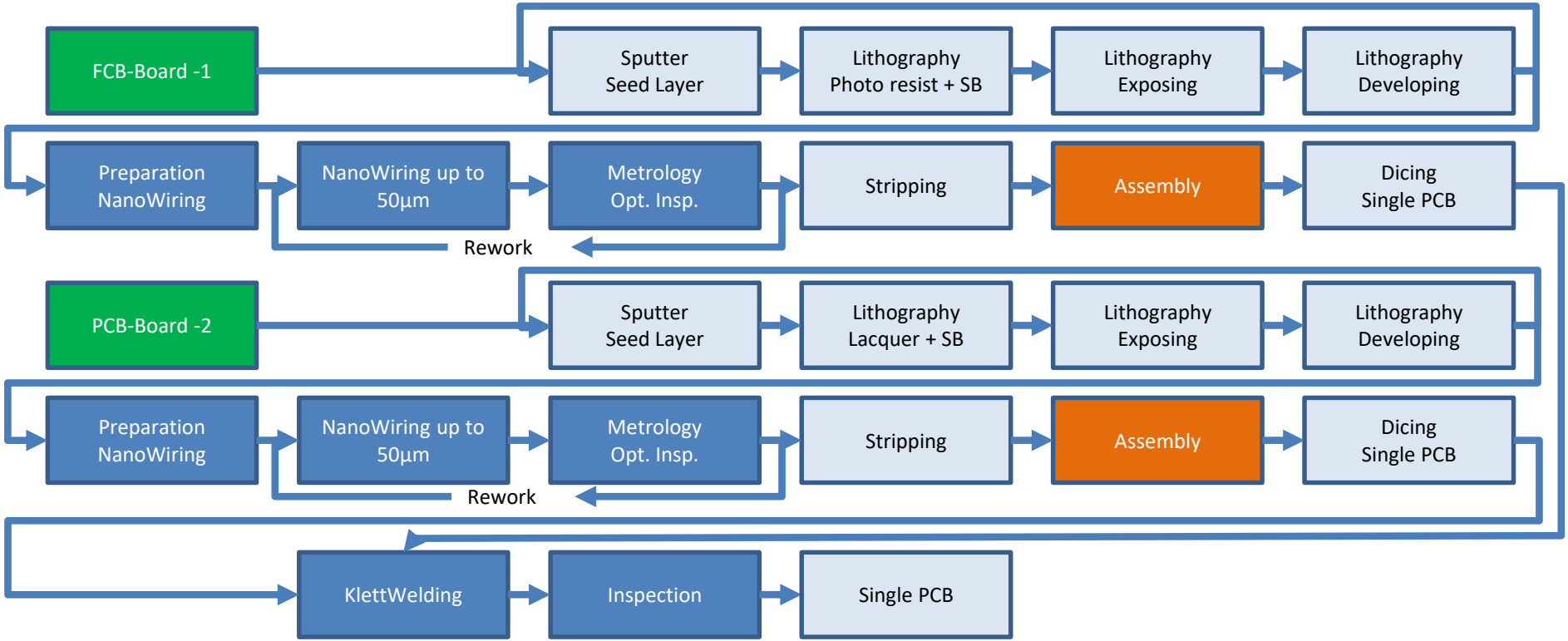
Technology basics

1.04 Process flow - Sensor / PCB



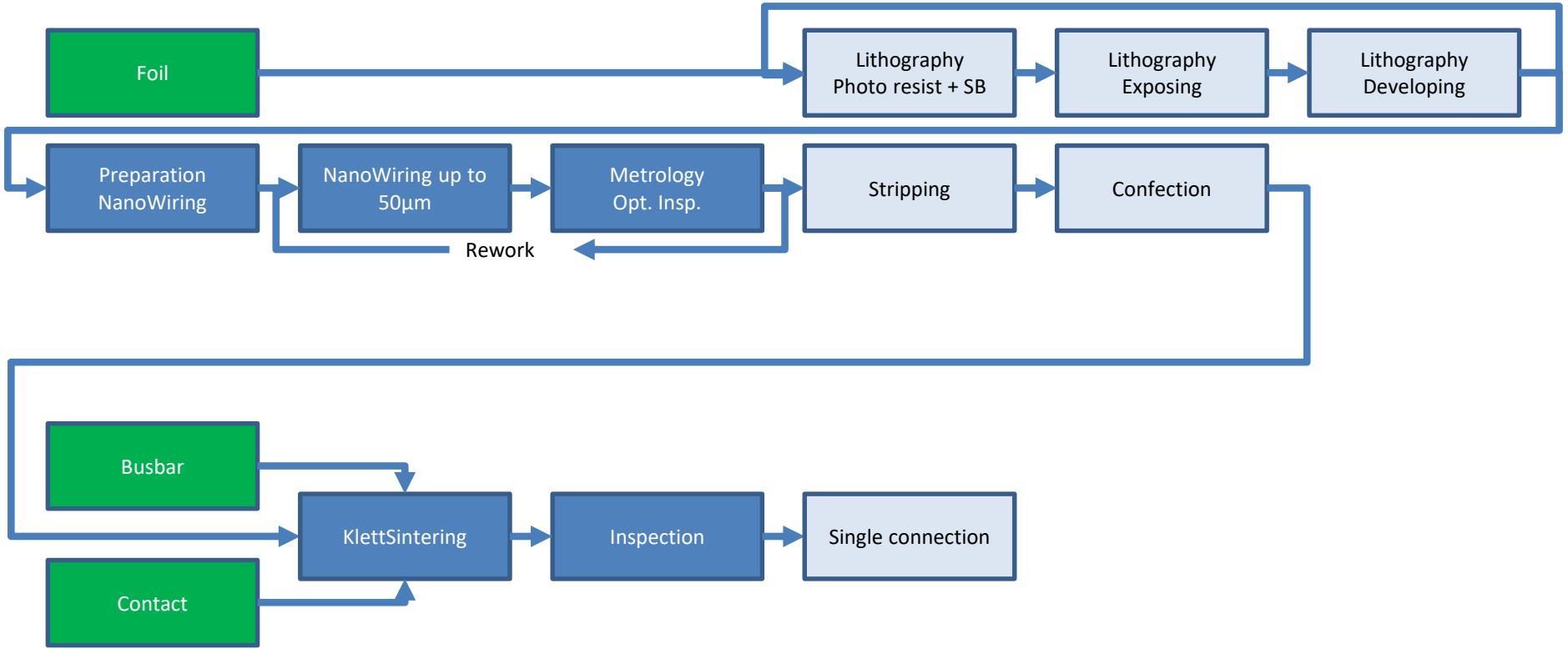
Technology basics

1.04 Process flow - FCB / PCB



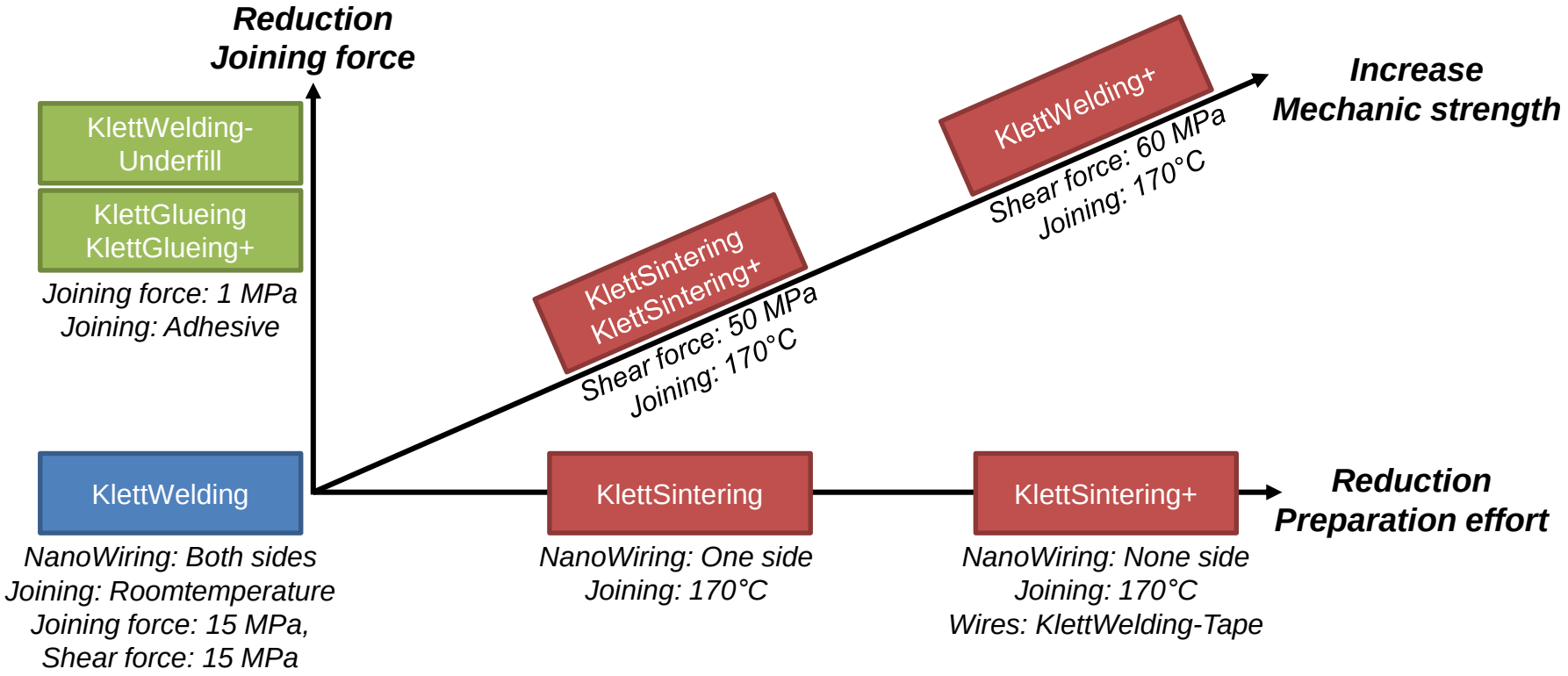
Technology basics

1.04 Process flow - KlettWelding-Tape



Joining methods

2.01 Overview



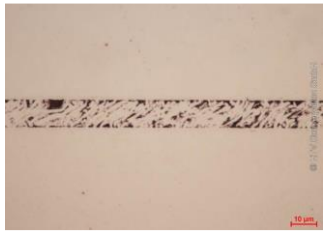
Joining methods

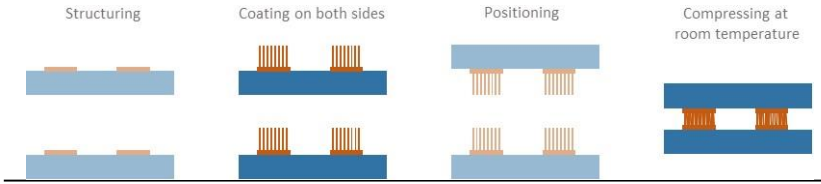
2.02 KlettWelding & KlettWelding+

KlettWelding

► highest connection speed, room temperature

1. **Preparation**
   - Both surface have NanoWiring Structure
2. **Terms of joining**
   - **Room temperature**
   - From 15 MPa
   - **From 60 ms**
3. **Result**
   - Shear force level approx. 15 MPa

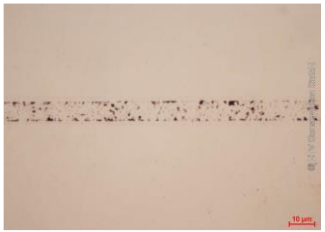


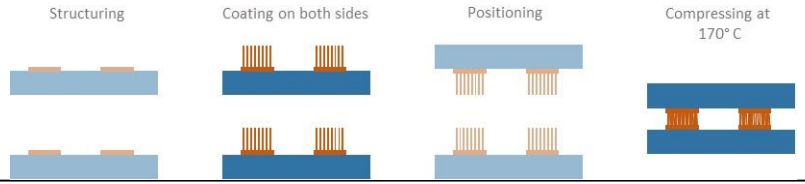


KlettWelding+

► highest strength connection

1. **Preparation**
   - Both surface have NanoWiring Structure
2. **Terms of joining**
   - From 170° C
   - From 10 MPa
   - From 10 s
3. **Result**
   - Shear force level approx. **60 MPa**





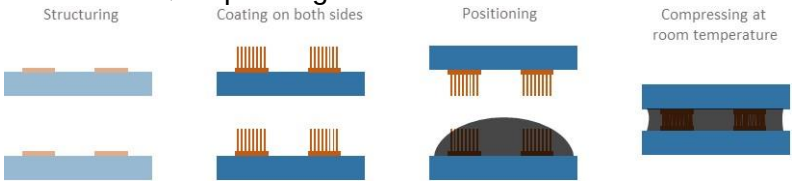
Joining methods

2.03 KlettWelding-Underfill

KlettWelding-Underfill

► low bond-force, low temperature

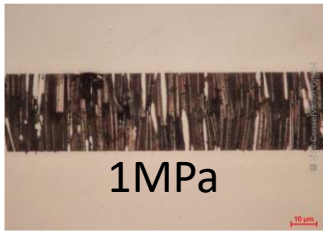
1. **Preparation**
   - Both surface have NanoWiring Structure
2. **Terms of joining**
   - **Low temperature**
   - **From 1 MPa**
   - From 60ms → Depending on activation of adhesive
3. **Result**
   - Shear force level approx. 10-50 MPa
     → depending on used adhesive

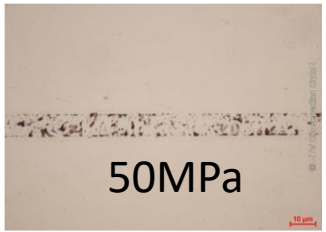


Overview Adhesive

► suitable for KlettGlueing/Underfill

Adhesive	Curing Method	Curing Temperature	Temperature Resistance
Structalit 8202	Thermal	130° C	-40° C / +200° C
Structalit 5811	Thermal	23° C	-40°C / +180°C
Polytec EP 630	Thermal	150° C	-55° C / +230° C
Polytec UV 2341 DC	UV / Humidity	23° C	-40° C / +150° C





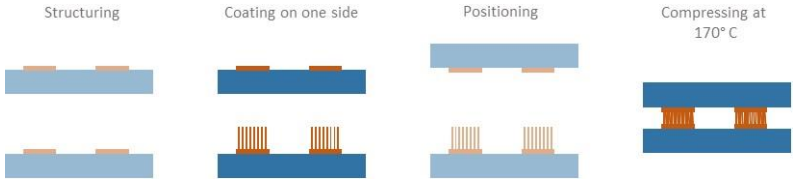
Joining methods

2.04 KlettSintering & KlettSintering+

KlettSintering

► lowest cost method, high strength connection

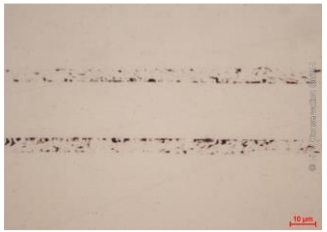
1. **Preparation**
   - One surface has NanoWiring Structure
2. **Terms of joining**
   - From 170° C
   - From 10 MPa
   - From 10 s
3. **Result**
   - Shear force level approx. **50 MPa**

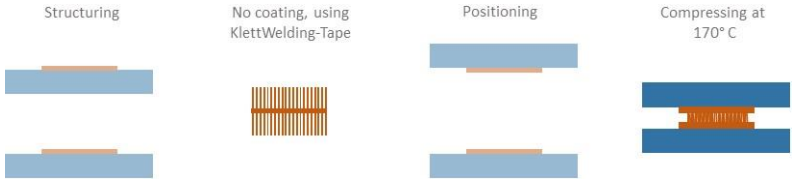


KlettSintering+

► lowest preparation effort, high strength connection, repairable

1. **Preparation**
   - None surface has NanoWiring Structure
   - Using KlettWelding Tape
2. **Terms of joining**
   - From 170° C
   - From 10 MPa
   - From 10 s
3. **Result**
   - Shear force level approx. **50 MPa**





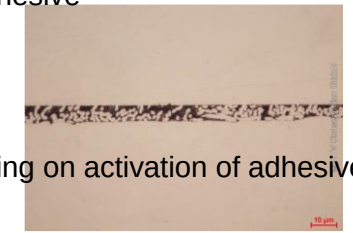
Joining methods

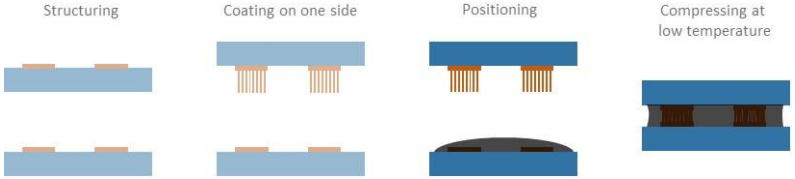
2.05 KlettGlueing & KlettGlueing+

KlettGlueing

► low bond-force, low temperature

1. **Preparation**
   - One surface has NanoWiring Structure
   - Using Low viscosity adhesive
2. **Terms of joining**
   - **Low temperature**
   - **From 1 MPa**
   - From 60 ms → depending on activation of adhesive
3. **Result**
   - Shear force level approx. 10-50 MPa
     → depending on used adhesive

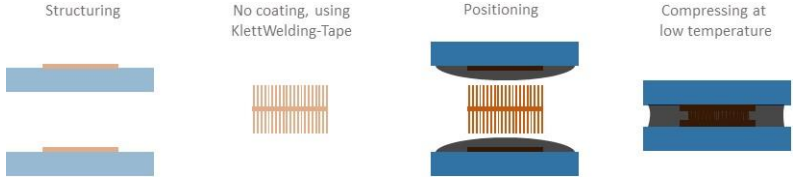




KlettGlueing+

► lowest preparation effort, low bond-force, repairable

1. **Preparation**
   - None surface has NanoWiring Structure
   - Using Low viscosity adhesive
2. **Terms of joining**
   - **Low temperature**
   - **From 1 MPa**
   - From 60 ms → depending on activation of adhesive
3. **Result**
   - Shear force level approx. 10-50 MPa
     → depending on used adhesive



Joining characteristics

2.06 Adhesive process

Q: Is it possible to underfill an assembled 6” (possibly later 8”) wafers stack with a 5-6um bond line thickness?

- As a rule, we use the low viscosity underfill directly by dispenser on the NanoWiring structure before joining. This is one of the advantages of our technology, that the bond is created even if the underfill has been applied in advance.
- Of course, the underfill can also be applied afterwards. But this is certainly more complex. In today's practice, many people struggle with the fact that the underfill only runs randomly and with a low reproducibility between the boundary layer between the substrates.
- Whether 6"" or 8" is irrelevant for the dispenser application, but it will certainly be a know how relevant process.

Q: How does the adhesive work by KlettGlueing process?

- By KlettGlueing process the NanoWires repress the adhesive and realize the connection to the its connection partner.
- The low viscosity used adhesive (e.g. Structalit 8202) closes the remaining spaces inside the connection.

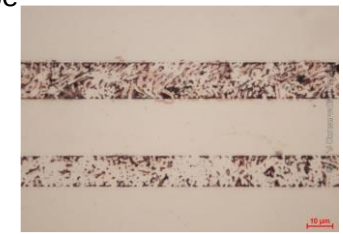
Joining methods

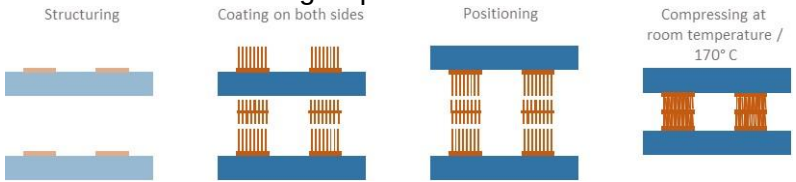
2.07 Hair Extension – Using KlettWelding-Tape

KlettWelding-Extension

► higher Bondline thickness

1. **Preparation**
   - Both surface have NanoWiring Structure
   - Using KlettWelding Tape
2. **Terms of joining**
   - **Room temperature**
   - From 15 MPa
   - From **60 ms**
3. **Result**
   - Extended Bondline thickness due to usage of KlettWelding-Tape

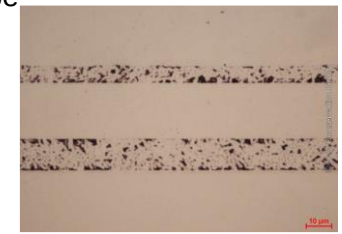


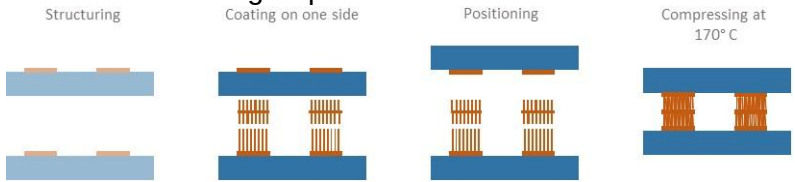


KlettSintering-Extension

► higher Bondline thickness

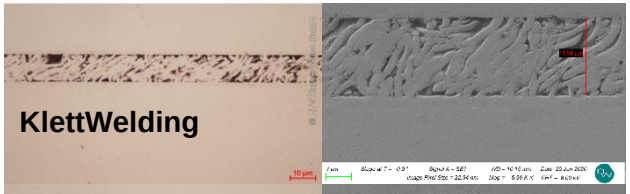
1. **Preparation**
   - One surface has NanoWiring Structure
   - Using KlettWelding Tape
2. **Terms of joining**
   - From 170° C
   - From 10 MPa
   - From 10 s
3. **Result**
   - Extended Bondline thickness due to usage of KlettWelding-Tape

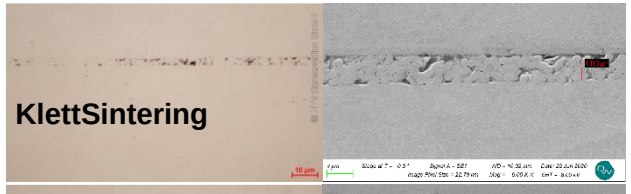


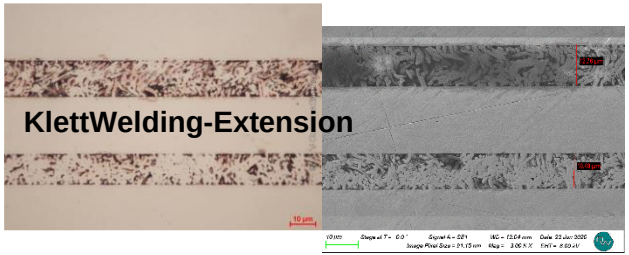


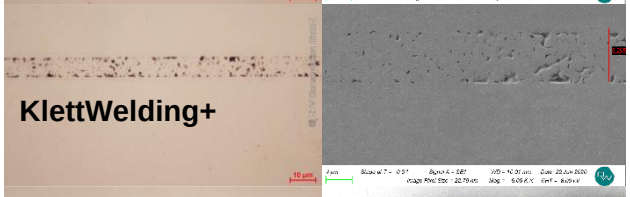
Joining methods

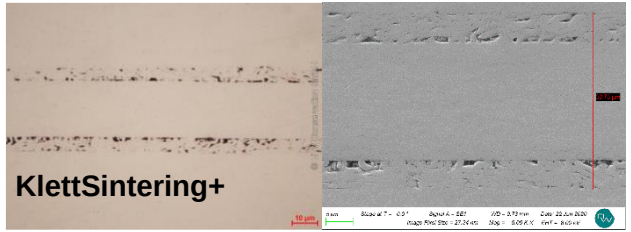
2.07 Compact Overview

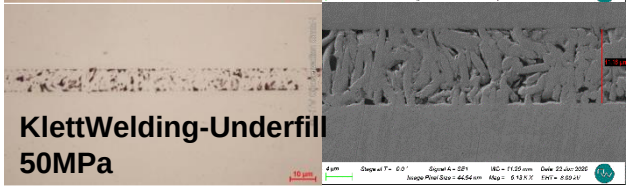


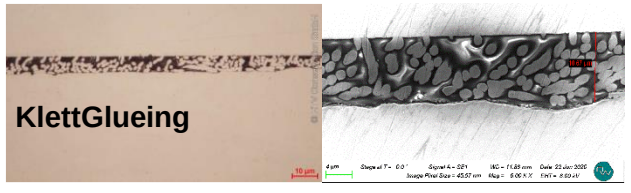


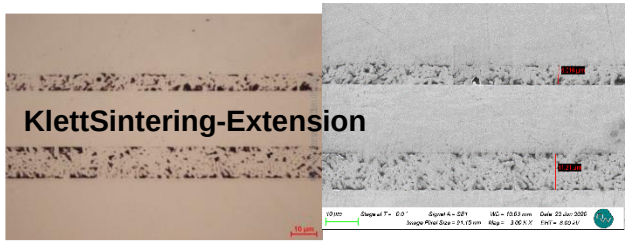












Joining methods

2.08 Typical applications

1) KlettWelding

- Highest speed per piece / pick and place machine capable
- Flip-Chip
- Semiconductor production
- Assembly joining - FPC/PCB, PCB/PCB
- Plastic Joints
- Die Attach
- Temperature sensitve devices
- (area processes are necessary)

2) KlettWelding+

- Automotive-BUSBAR electricity transport by the car / airplane / truck/ ...
- Case technology
- Power Electronics / Die Attach
- Contact connection
- DCB production
- High strength connections

3) KlettWelding-Underfill

- Automotive-BUSBAR electricity transport by the car / airplane / truck/ ...
- Assembly joining - FPC/PCB, PCB/PCB
- Case technology
- Temperature sensitve devices

Joining methods

2.09 Typical applications

1) KlettSintering

- Automotive-BUSBAR electricity transport by the car / airplane / truck/ ...
- Case technology
- Power Electronics / Die Attach
- Contact connection
- Ceramics to metal (e.g. Sensors)

2) KlettSintering+

- Automotive-BUSBAR electricity transport by the car / airplane / truck/ ...
- Highest flexibility
- Placement
- 3-D electronics

3) KlettGlueing

- Assembly joining - FPC/PCB, PCB/PCB
- Temperature sensitve devices
- Fragile devices

4) KlettGlueing+

- Assembly joining - FPC/PCB, PCB/PCB
- Temperature sensitve devices
- Fragile devices
- Prototypes
- Repair of interconnections

Joining characteristics

2.10 Applications - LED

Q: What are the advantages for LED‘s by using NanoWired technologies?

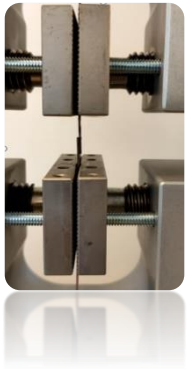
- **Basic Knowledge:**
  - Above 120°C the doping under voltage decreases → P-N junction is disappearing / dying
  - Thus, a light emitting diode may be operated up to 119°C, as soon as it reaches 120°C it dies very fast the heat death.
  - If an exact temperature measurement and a good heat connection can be created → you can bringt the LED closer and closer to its maximum temperature load.
  - To get the maximum light output out of light emitting diodes, light emitting diodes have not been operated at their ideal operating point (maximum efficiency) for a long time, but at the maximum current point at which there is just no backdoping.
  - Normal soft solders lose their mechanical strength at approx. 115°C.
  - Solder layers already expand considerably and the internal resistance of the transition increases → leads to a further increase in temperature in the joint due to the power loss → maximum light output limit of light emitting diodes cannot be reached with normal soft solders that do not have an additive for increased temperatures.
- **KlettWelding:**
  - The pure copper not only conducts the current better and thus contributes a negligible heating of the connection, but also the resulting power loss is better conducted out of the light emitting diode, due to the higher heat output of copper.
  - Furthermore, the strength of the connection and thus also its performance at 120°C remains unaffected, since the melting temperature of copper is 1.085°C, there are no mechanically relevant changes in the material up to over 500°C.

Joining characteristics

2.11 Mechanic strength

Q: Do you have comparison test data on influence of strength (Pull and shear) from different connecting conditions?

- KlettWelding: approx. 15 MPa
- KlettWelding+: approx. 60 MPa
- KlettSintering: approx. 50 MPa
- KlettSintering+: approx. 50 MPa
- KlettGlueing/KlettGlueing+: approx. 10-50 MPa depending on used adhesive



Q: Shear force: depends on different end products, how's your experience?

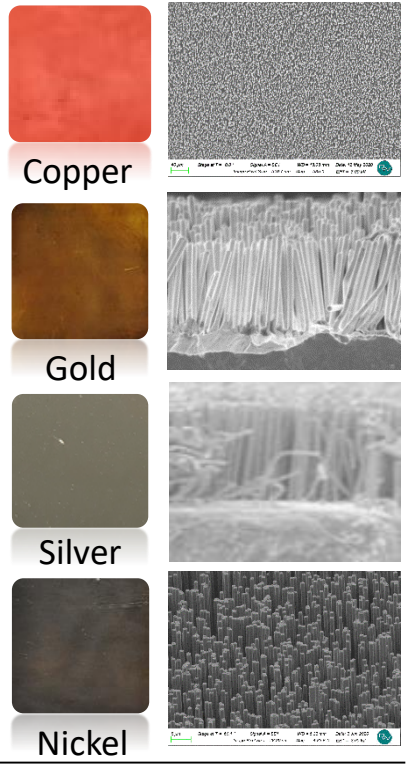
- The resulting shear strength depends mainly on 4 factors, joining method, joining temperature, joining pressure and joining time. The material also has an influence on the systemic final strength, as the strength of the joint cannot be higher than the basic strength of the material.
- The optimum values of temperature, pressure and time depend on the used joining method and on the material of the elements.

Joining characteristics

2.12 KlettWelding-Tape

Q: Which materials are available for KlettWelding tapes?

- NanoWired can currently supply the following material variants of KlettWelding Tape:
  - Core materials: copper, polyimide / Standard = copper
  - Core thickness Cu: 5µm, 20µm, 100µm,... 2mm / Standard = 20µm
  - Core thickness PI: 12µm, 25µm, 50µm
  - NanoWiring diameter: 30nm,... 4µm / Standard = 1µm
  - NanoWiring fill factor: 10%,... 40% / Standard = 18%
  - NanoWiring material: copper, silver, gold, nickel / Standard = copper
  - Hybrid designs are also possible, in which case NanoWired incorporates a nickel diffusion barrier.
  - Homogeneity: Various quality classes are available for the copper NanoWiring. Standard, Premium, Special
- Special feature of Isolation-KlettWelding-Tape: The Isolation-KlettWelding-Tape is also available in structured and with vias.

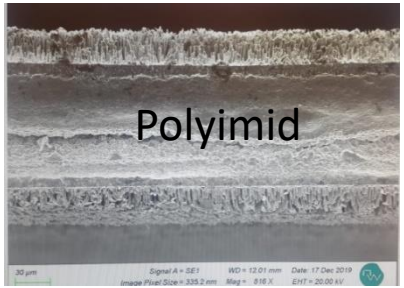


Joining characteristics

2.13 KlettWelding-Tape

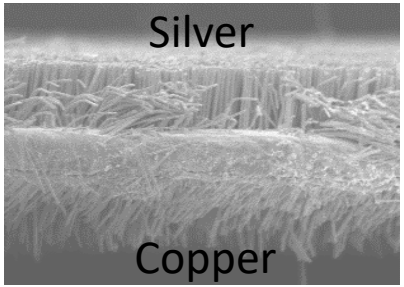
Q: What is the material for Isolation KlettWelding-Tape? What is the dielectric strength?

- We use Polyimid as isolation material for Isolation KlettWelding-Tape.
- The common thicknesses are possible:
  - Asia: 12 µm
  - Europe: 25 µm (Dielectric strength 7,8 kV)
  - Additional: 50 µm / 75 µm



Q: What are hybrid KlettWelding-Tapes needed for?

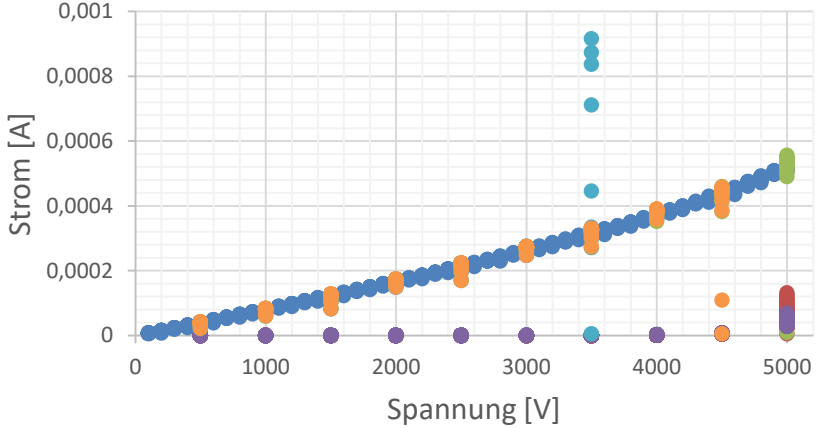
- Especially when using power electronics assemblies and components, these are supplied with a SILVER SURFACE.
- To connect such modules and assemblies with a copper-clad PCB board, NanoWired GmbH has developed a hybrid KlettWelding-Tape with integrated diffusion barrier.
- One side of the surface is SILVER - NanoWiring and the other side is made of copper NanoWiring. This makes it possible to directly connect two substrates with different metallized surfaces by means of KlettSintering+.
- Penetration and infiltration of the copper by silver atoms is reliably prevented by the nickel diffusion barrier.

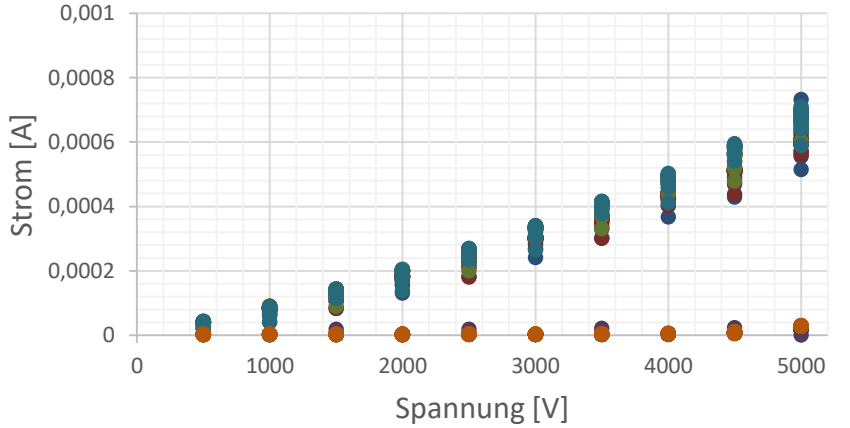


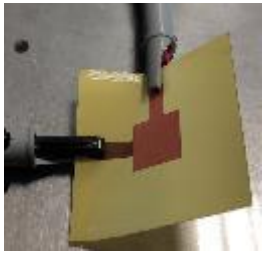
Protection: Isolation-KlettWelding-Tape

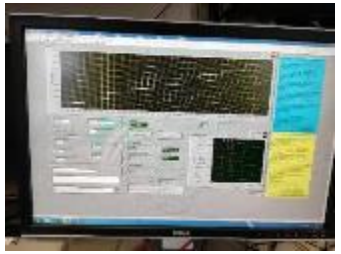
2.13 KlettWelding-Tape

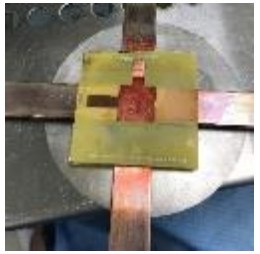
A: Level: 2.8kV, 7.8kV, >10kV











Joining characteristics

2.13 KlettWelding-Tape

Q: What is the CTE and heat transfer of different materials?

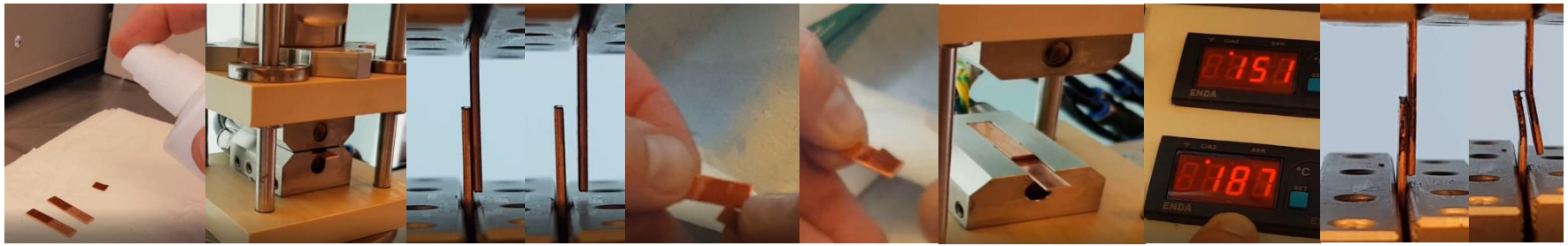
Description	α in 10^{-6} K^{-1}	λ in W/(m·K)
Polyethylen (HD-PE)	150 ... 200	0,33...0,57
Polypropylen (PP)	100 ... 200	0,23
Polytetrafluorethylen (PTFE)	100 ... 160	0,25
Polycarbonat (PC)	60 ... 70	0,2
Polyamid (PA)	60 ... 150	0,25...0,35
Polyimid (PI)	8 ... 15	0,37...0,52
Zink	30,2	110
Magnesium	24,8	170
Aluminium	23,1	75...235
Zinn	22	67
Messing	18,4 ... 19,3	120
Silber	18,9	429
Kupfer	16,5	240...401
Gold	14,2	314
Magnesiumoxid	13,1	
Nickel	13	85
Konstantan (bei −191 ... 16 °C)	12,22	
Siliziumdioxid (Quarz)	012 ... 16	1,2...12
Stahl	11 ... 13	48...58
Platin	8,8	71
Titan	8,6	22
Aluminiumoxid, kristallin	5,6 ... 7,0	28
Germanium	5,8	
Borosilikatglas	3,3	
Silizium	2,6	163
Technische Keramik	2 ... 13	
Quarzglas (Siliziumdioxid)	0,54	1,2...12

Joining characteristics

2.14 KlettWelding-Tape // repair a destroyed connection

Q: Is it possible to repair a destroyed connection?

- Yes, by using the KlettWelding-Tape the destroyed connection between two components can be restored. This does not require a new surface treatment with NanoWiring.
- **KlettSintering+**
  By KlettSintering with KlettWelding-Tape (from 170° C) a new connection can be made. Whether 6"" or 8" is irrelevant for the dispenser application, but it will certainly be a know how relevant process.
- **KlettGlueing+**
  Alternatively, the mechanical strength can be achieved by means of adhesive, the KlettWelding-Tape ensures the electrical contact of the components.



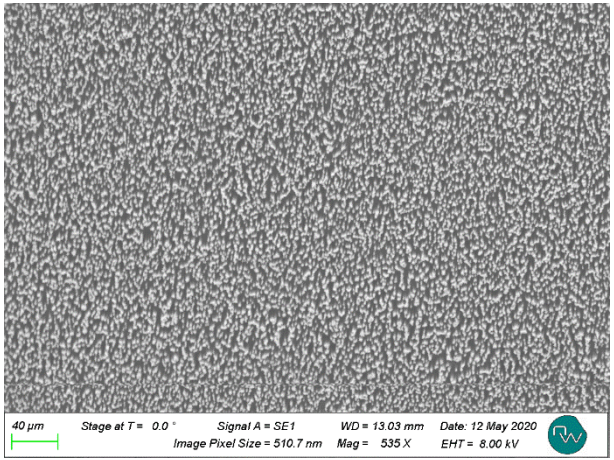
Activation **KlettWelding** **15MPa Sheerforce** **KlettWelding-Tape Repair** **KlettSintering+** **60MPa Sheerforce**

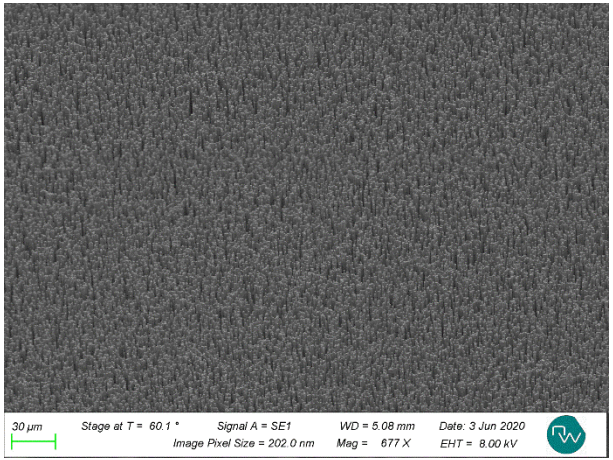
Joining characteristics

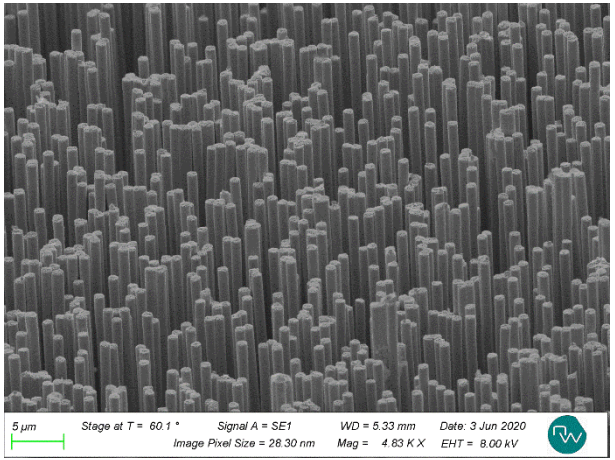
2.15 KlettWelding-Tape- Surfaces

Q: What do the surfaces of the KlettWelding-Tapes look like?

- The used base metallization and the materials of the NanoWires have differences in their length variation.
- The quality of the electrolyte used can also influence the homogeneity.
- The distribution and diameter of the NanoWiring structure have a negligible scattering.







Joining characteristics

2.16 Quality data

Q: Do you have cross section photos after connection?

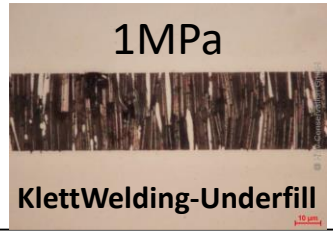
- We have recorded various SEM analyses and micrographs. We can gladly provide a selection of images for this purpose.

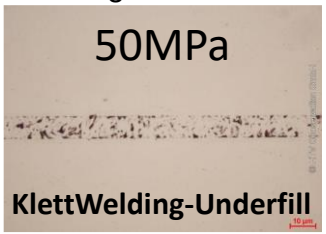
Q: Is Metal bonding used?

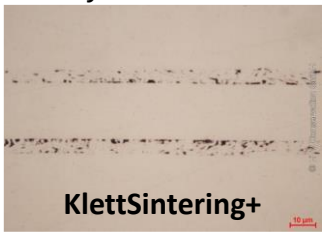
- We have joined different metals together. In the NanoWiring structure we usually always use the same metals, so that a mixing of metals is not possible. If different types of metals are to occur directly in the connection zone, we build appropriate diffusion barriers into the structure to prevent mixing.

Q: How to do Electrical test after connecting?

- The electrical test can be performed with a simple resistance meter. The resulting connection is gas and watertight. It has a residual porosity between 1 and 9% depending on the joining method. All temperature-affected joining methods (KlettSintering, KlettSintering+ as well as KlettWelding+) have a denser joint, KlettWelding, KlettWelding-Underfill, KlettGlueing and KlettGlueing+ have a more porous joint but a higher elasticity.







Joining characteristics

2.17 Quality data

Q: What

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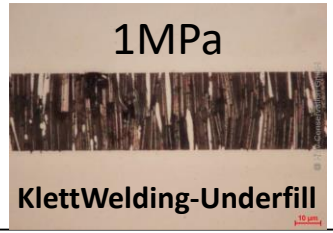
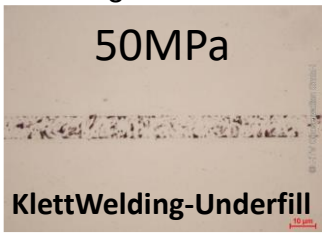
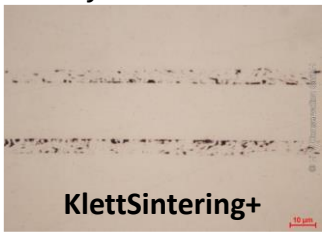




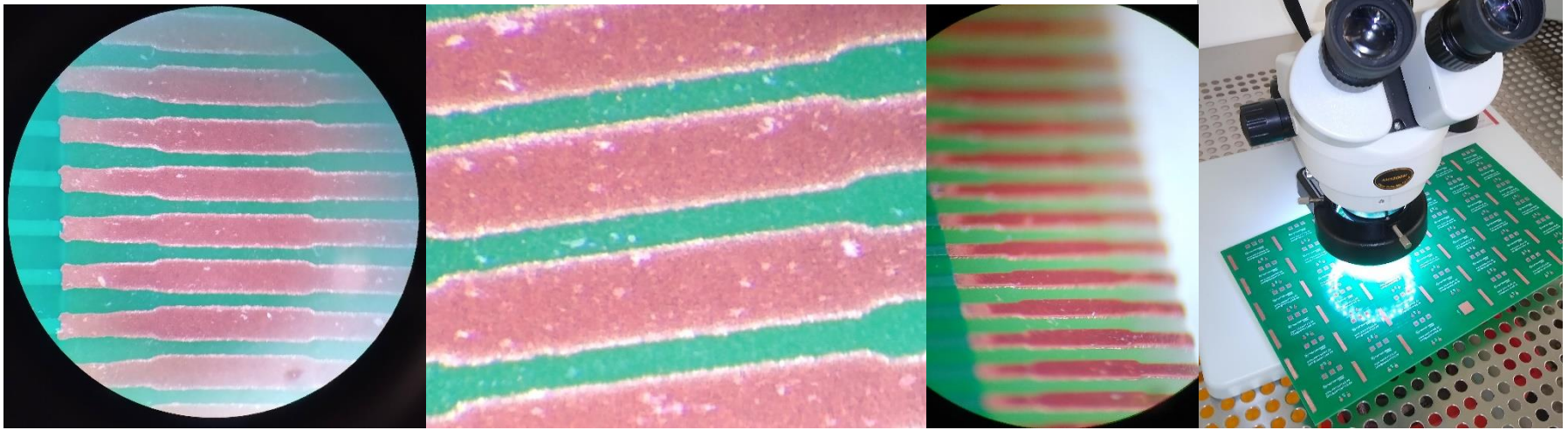


Joining characteristics

2.18 Quality data

Q: What equipment do we need to inspect the flaws of NanoWiring?

- It is not necessary to invest in high-tech equipment.
- Already a simple stereo microscope worth 150€ is sufficient to inspect the flaws of NanoWiring.



Joining characteristics

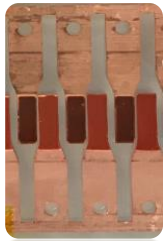
2.19 Reliability

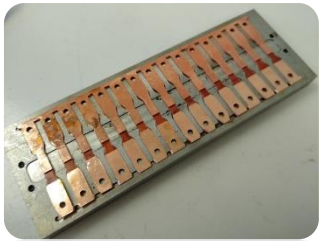
Q: Is there any Alloy formation or not?

- We try to design the connection in such a way that only pure metal structures can be found in the KlettWelding / KlettSintering / KIettGlueing zone, or corresponding nickel diffusion barriers are designed in.

Q: Do you have Reliability test results after connection (For Confirmation of resistance value change from TC etc.)?

- We have carried out reliability tests especially for KlettWelding+, KlettSintering and KlettSintering+. For this purpose, samples were stored at 150° C and the electrical and mechanical strength was tested after "0h“, "500h“, "1000h“ and “4000h”.In parallel, the same analysis were performed at 85° C and 85% RH and cycling between -50° C and 140° C.
- All these tests show that the connection quality does not suffer any loss of performance under load.
- In addition, a study is currently being conducted at NanoWired where our customers can purchase 10T€, which will run for one year and intensively analyses the behavior with regard to ageing and storaging.

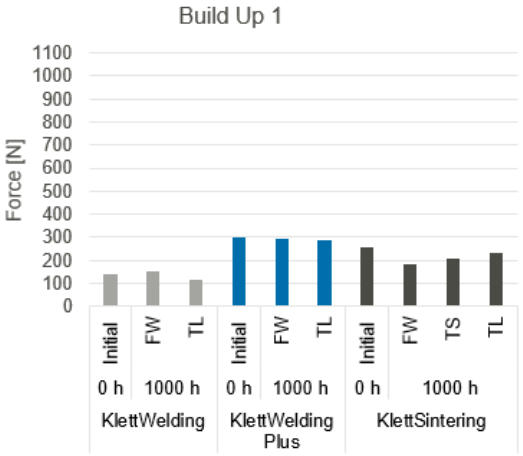


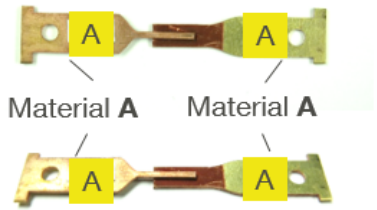


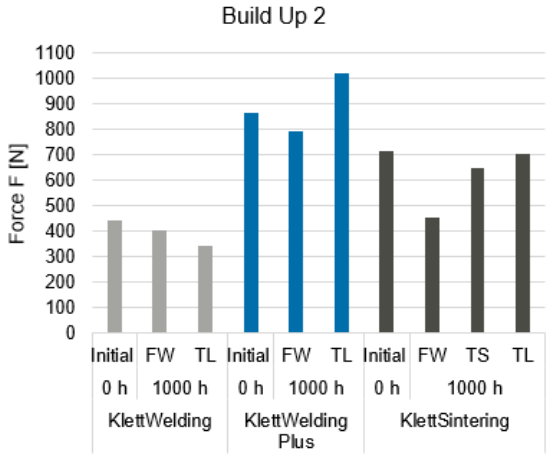
Shear strength

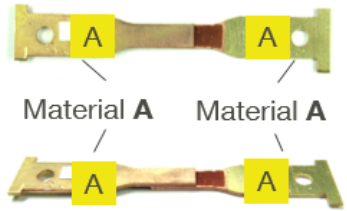
0h / 500h / 1000h

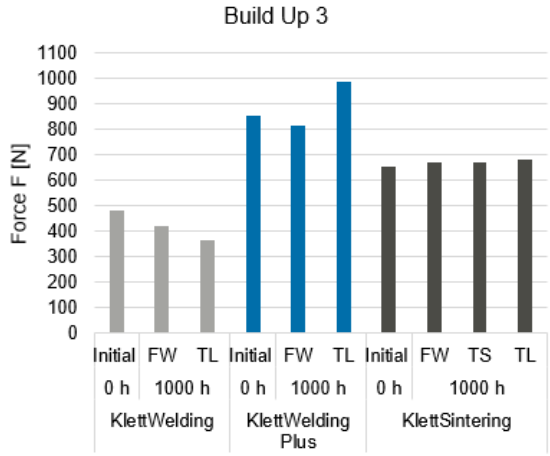
FW: 85°C/85%rh
TL: 150°C
TS: -40°C/+150°C

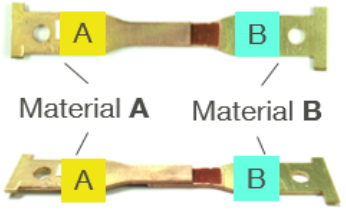






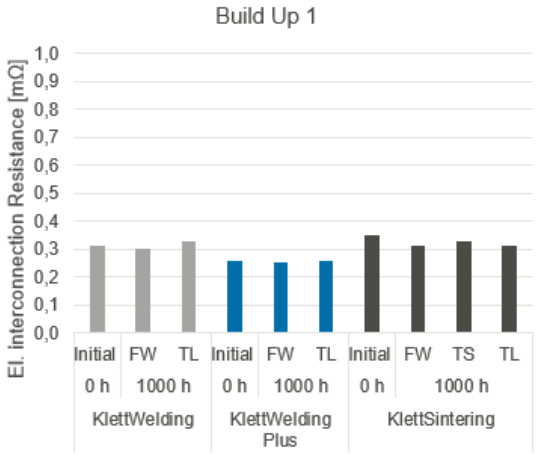


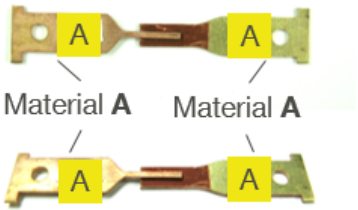


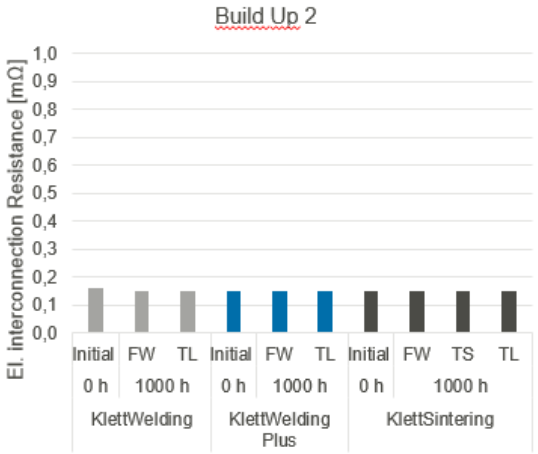


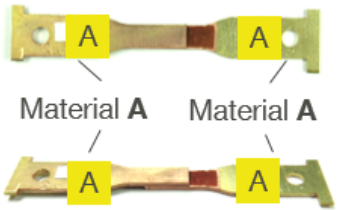
Electrical Interconnection resistance

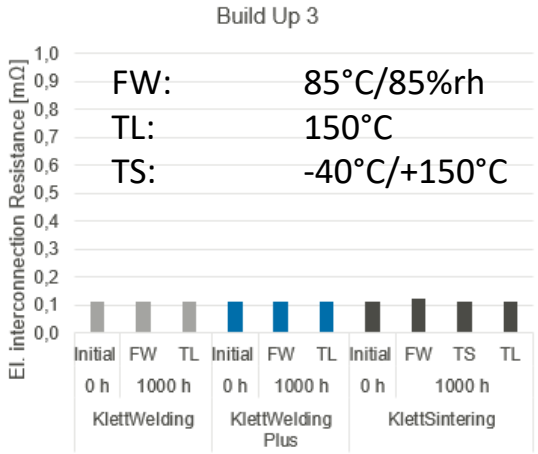
4 wire measurement



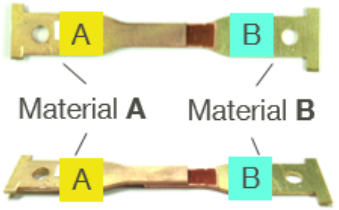








FW: 85°C/85%rh
TL: 150°C
TS: -40°C/+150°C



Joining characteristics

2.20 Surface behaviour

Q: Is there any affection on surface oxide film?

- We distinguish two areas in which we serve the topics:
- NanoWiring → As long as we make copper NanoWiring a residual oxide formation on the surface has a negligible effect. The acidic electrolyte dissolves the traces of oxidation, so that the process is not affected. In general, a clean and grease-free surface must be available for the NanoWiring process.
- If gold electrolyte is to be used, appropriate caution must be exercised, as the gold electrolyte is not acid-based.
- KlettWelding, KlettSintering, KlettGlueing → As we currently do not apply any oxide-inhibiting layers on the NanoWiring structures, we currently always use a KlettWelding Activator to remove the OXID layer on the copper. Slight oxidation does not play a role in this process. The layers are mechanically stressed when the hair is woven together, which ensures that diffusion and contact still take place. For reduction, both commercially available wet chemical and dry chemical processes are available, and hydrogen plasma can be used as an alternative.

Q: Do we need Plasma treatment as surface treatment before NanoWired processing?

- Not in general. If we have carried out an organic treatment, for example by lithographic processes, we use oxygen plasma to remove all organic residues.
- Before KlettWelding, we currently activate the surface with KlettWelding Activator or hydrogen plasma

Q: Do we need any reduction treatment, flux, etc. when we connect?

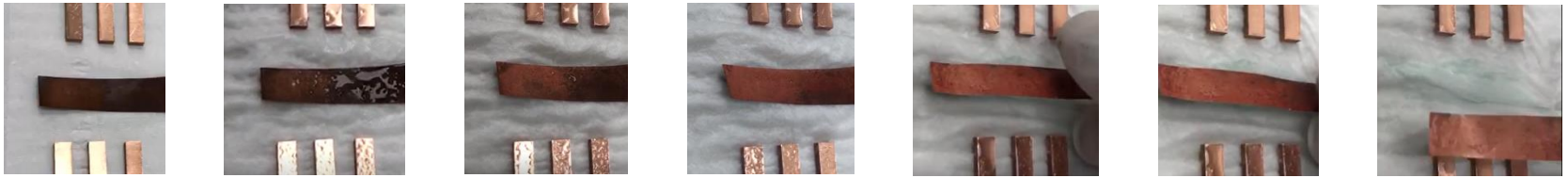
- At the moment we are doing this, but we are developing further, so that in future it isn't necessary anymore

Joining characteristics

2.21 Oxidation of the NanoWiring structures

Q: How long can NanoWiring structures be stored?

- At present, there are no observations that NanoWiring structures that have been stored for one year show any change in connection behavior, connection strength or conductance values.
- In the pictures on the left side you can see Multi Angle NanoWiring structures which have been stored for 2 years in a humid environment. As can be seen under the SEM, an extremely strong oxidation of the surface has taken place. The surface was cleaned before use with KlettWelding activator. The reduction is clearly visible in the next SEM image, as is the fissure of the structure. The KlettWelding tape was then used for a KlettSintering+ process. Subsequent tensile tests / shear tests have shown no change in tensile strength.

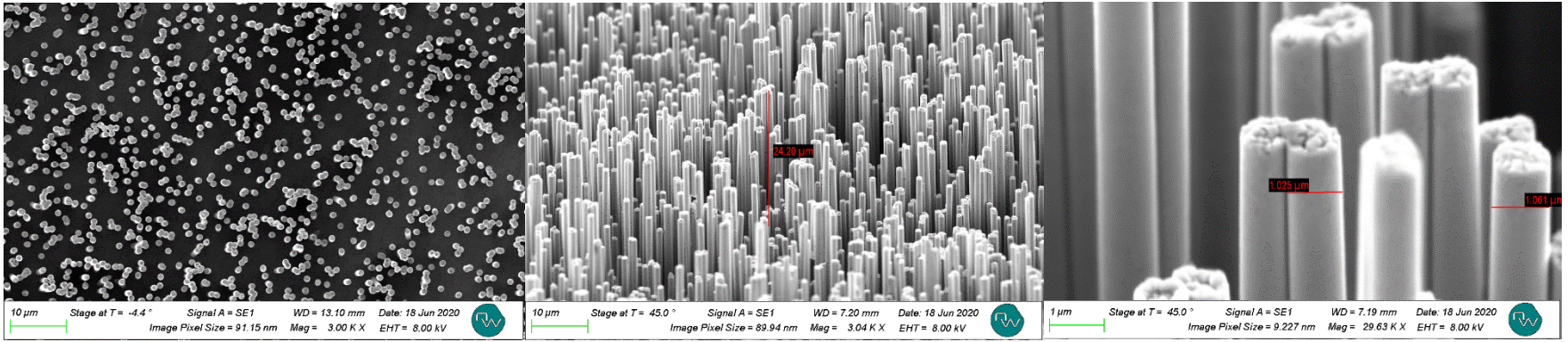


>2 Years age | **Activation** | **+5Sek** | **+10Sek** | **+15Sek.** | **+20Sek.** | **Final**

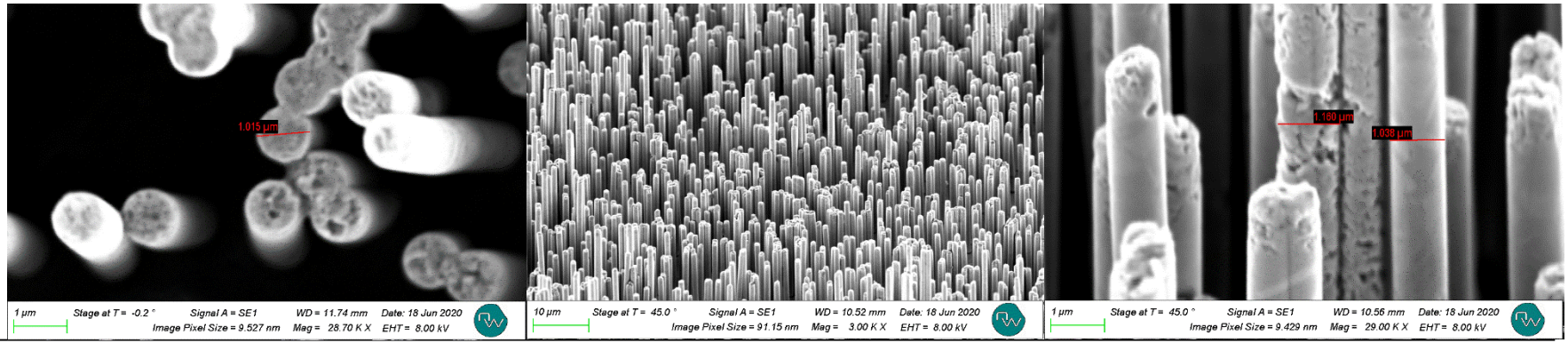
Joining characteristics

2.22 Oxidation after 2 Years normal storage (Rectangular-Tape)

Oxidized NanoWiring

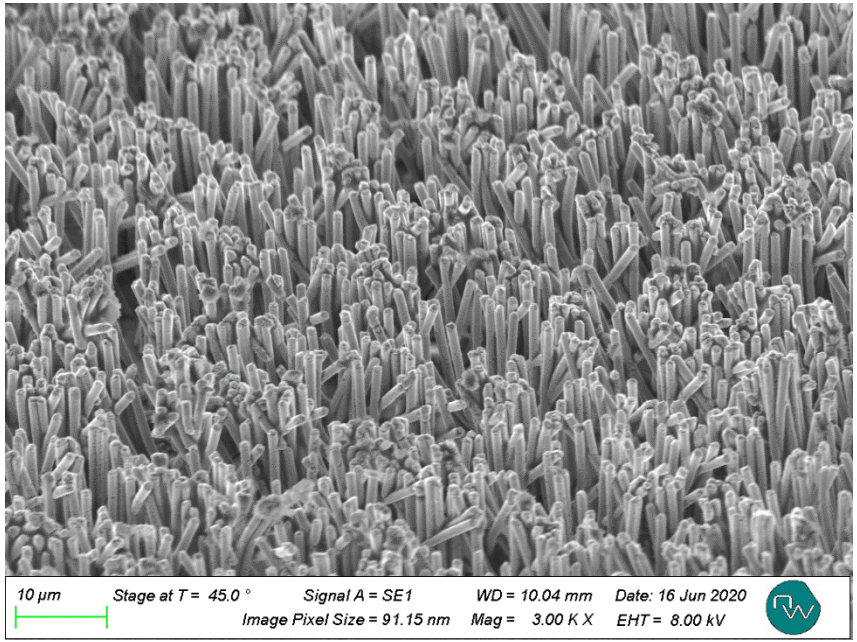


Activated NanoWiring

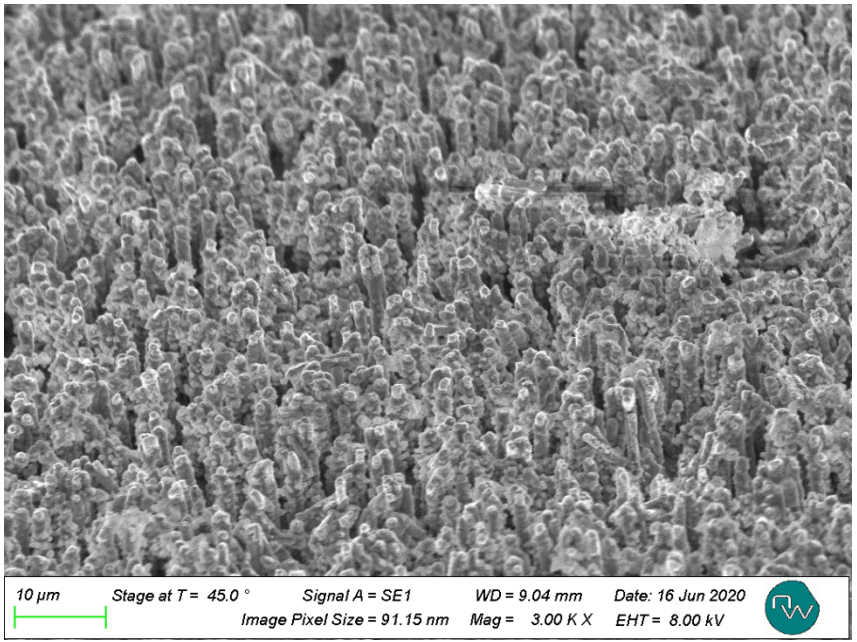


Joining characteristics

2.23 Oxidation after 2 Years storage with WATER (Multi-Angle-Tape)



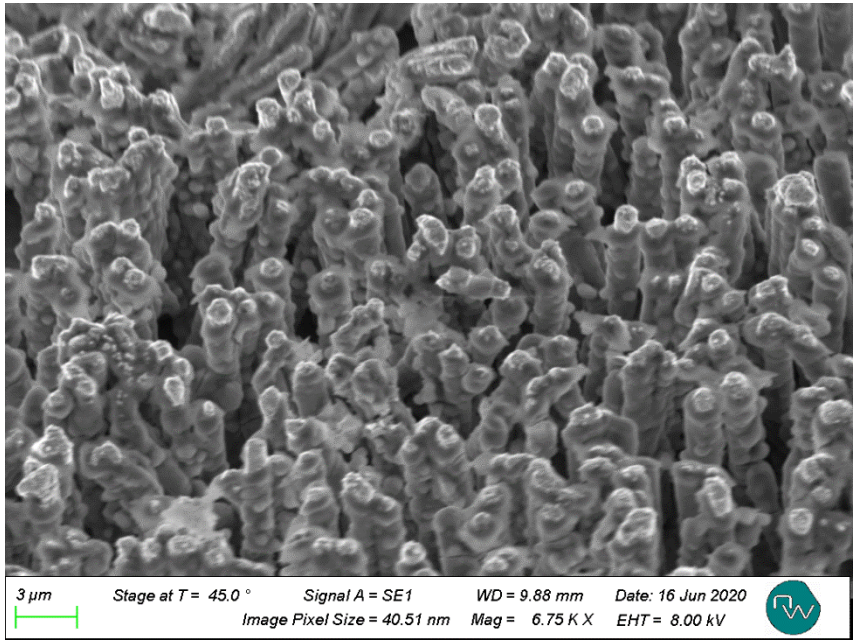
NanoWiring structure after 2 years storage



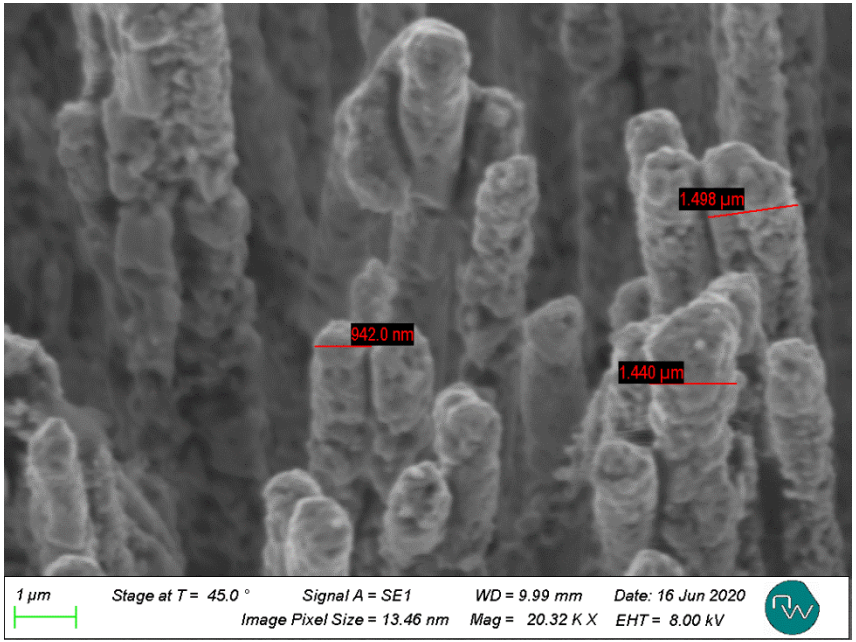
NanoWiring structure after 2 years moisture

Joining characteristics

2.24 Oxidation after 2 Years storage with WATER (Multi-Angle-Tape)



NanoWiring structure after 2 years moisture



NanoWiring 2 years moisture - activated

To satisfy your hunger

NanoWired Cookie-Box

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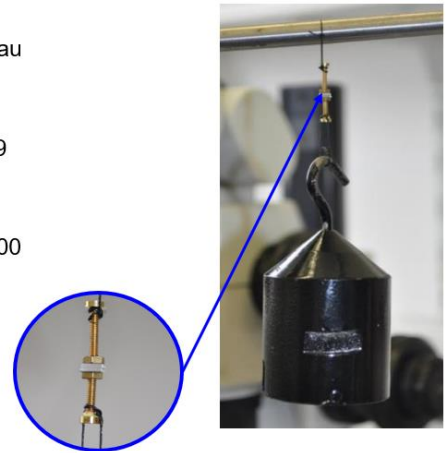

Science Life Gewinner Konzeptphase NanoWired Venture Cup 2016

STEP AWARD Preisträger 2018

HERMES AWARD 2019

GERMAN INNOVATION AWARD '20 WINNER