SOLDERING OF ALUMINUM WITH ROSIN BASED AND INORGANIC FLUXES

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»Materials and Technologies for MEMS Packaging«

TAMURA ELSOLD: Product Portfolio

TAMURA ELSOLD: The full range of soldering materials

- Solder
  - Bar, Ingot etc.
  - Wire (flux core, solid)
- Solder Pastes
- Fluxes

TAMURA Corp.

- Solder Pastes
- Solder Fluxes
- Solder Resists

TAMURA ELSOLD: History

1906

Bleiwerke Goslar

1924

Foundation of Tamura Radio Trading Comp.

1954

Trademark ELSOLD arises
Production of solder products

1956

First Tamura Solderite Flux

1960s-1980s

First Tamura Masks and Solder Pastes

2010

ELSOLD GmbH & Co. KG becomes subsidiary of JL Goslar

2013

Opening of new facility in Ilsenburg on a 5,000 m² site with 1,350 m² production area and 320 m² office space

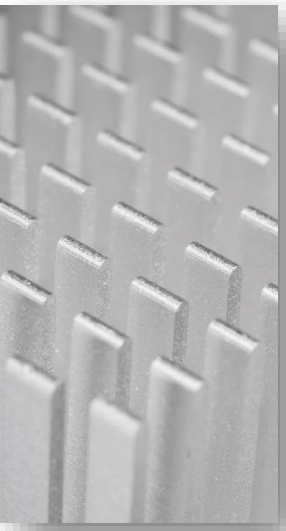
2017

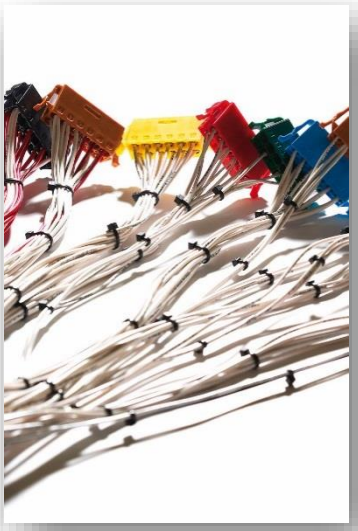
ELSOLD becomes new member of TAMURA Corp.

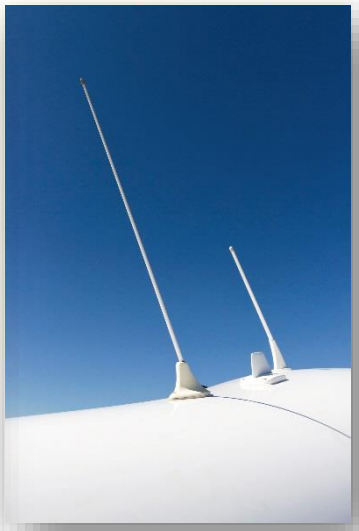
2018

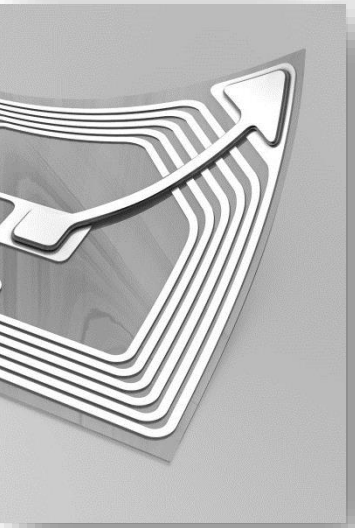
TAMURA ELSOLD GmbH

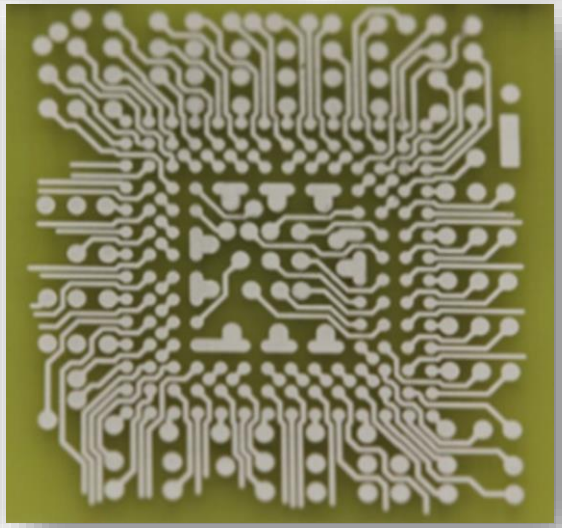
Motivation: Applications of Aluminum for Electronics











Current development: soldering of larger components and structures

Future: Macro ➔ Micro

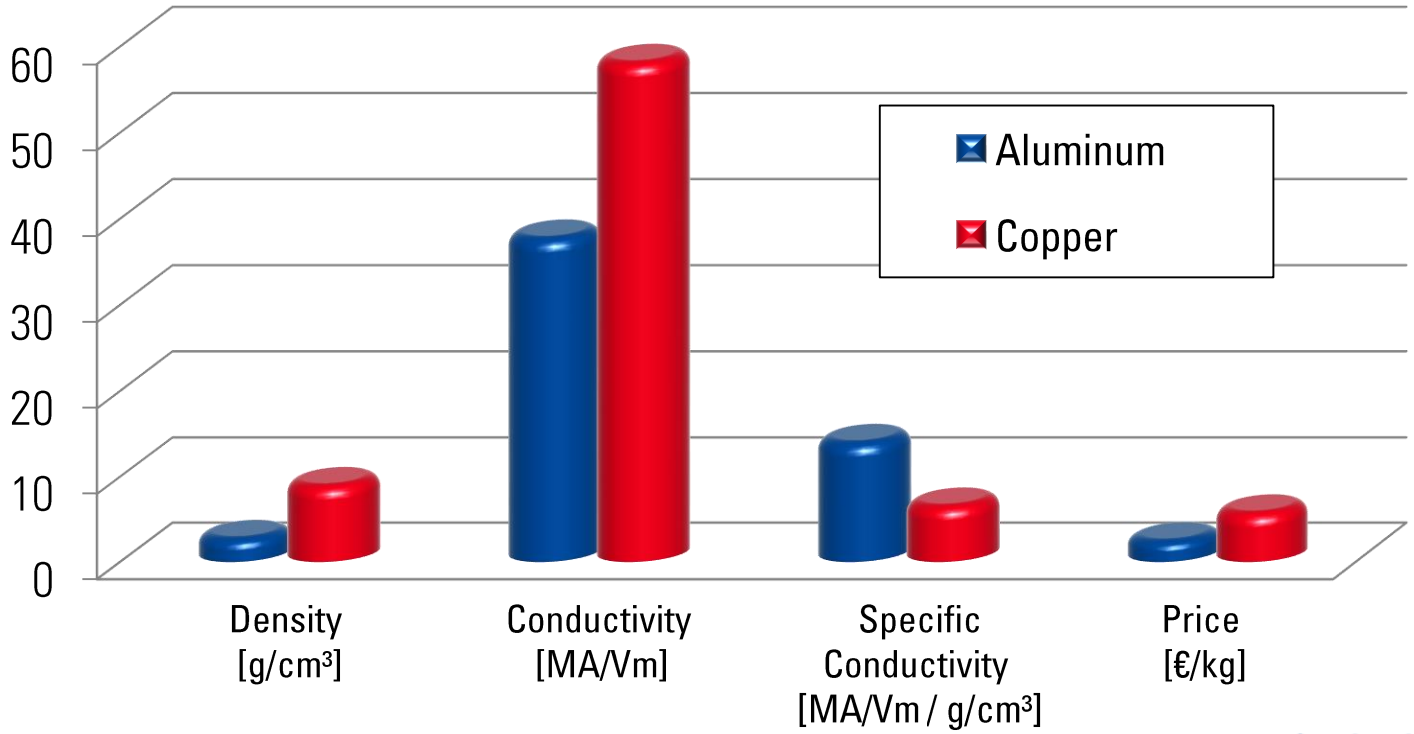
Closing gap &

solving of chicken-and-egg-problem:

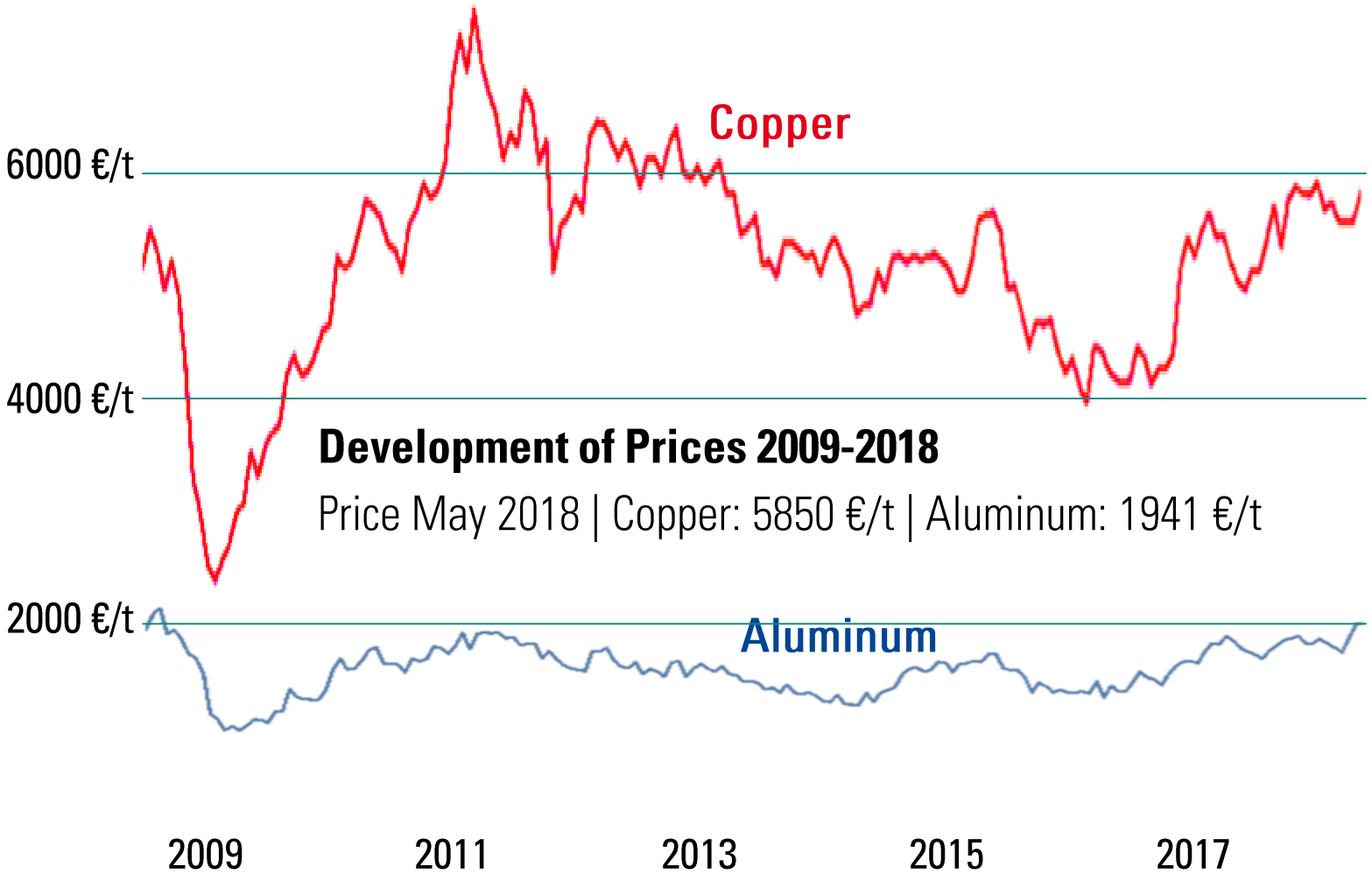
Development of Al-components, pcbs with Al conductive paths (ENAS AioLi project) and soldering technology /fluxes

Motivation: Properties of Aluminum

- Up to 60% lighter than copper cables of comparable current carrying capacity
- Advantages at high-frequency technology due to skin effect:
  - Resistance factor 1.7 for DC
  - Resistance factor 1.7 for HF
- Advantages for transformers: Reduced springback at spool winding



Motivation: Price of Aluminum vs Copper



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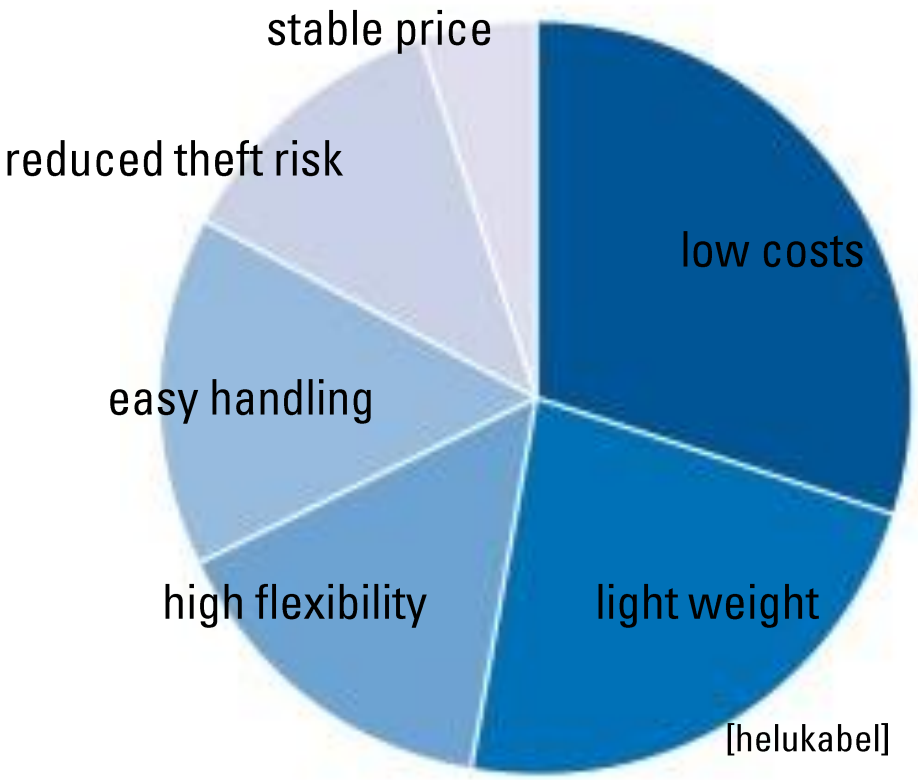
Motivation: Reasons for use of Aluminum Cables



Challenges of Aluminum Joining

Joining of Aluminum – Examples and Challenges

- Crimping – challenges: creep, only for specific geometries
- Brazing – challenges: Stabile oxide layer, process temperatures too high for thermal sensitive components
- Soldering – challenge: stabile oxide layer, non-removable with standard fluxes
  - Ultra Sonic Soldering/Bonding:
    - established for bond wires
    - special equipment and solder alloys necessary for soldering
  - **Soldering in standard processes, but with special fluxes**

Materials

- Pure Aluminum: good electrical properties, low strength
- Aluminum alloys: higher strength, more difficult to solder due to even more stable oxide layers (e.g. by MgO)

Challenges of Aluminum Soldering with Fluxes

Polylemma:

activity:
heavy reactive chemicals, e.g. fluorides, necessary to remove oxide layers

risk of corrosion:
residues of heavy reactive chemicals can cause strong corrosion

workability / storability:
heavy reactive chemicals may not react (inadequately) during production or storage. Limitation of usable chemicals, conventionally used for fluxes

appliability:
flux has to be applied in common processes, although typical substances cannot be used, e.g. to obtain good rheological properties

Flux types for soldering of Aluminum

- **Flux classification acc. to "old" DIN8511**
  - **F-LW-1: solder forming Tin- and Zinkchlorides (INH1):**
    - **Best activity [Down 1957]**
    - **High necessary soldering temperatures >400 °C**
    - **High corrosivity**
  - F-LW-2: organic compounds (ORH0)
  - F-LW-3: organic halogen compounds (ORH1)
- **Alternative: ROH1/ REH1 – improved protection against corrosion**

Development of Fluxes for Soldering Aluminum

Development of low melting INH1/F-SW-1-Flux

- Highest activity
- enlarged areas of application due to lower temperatures
- Flux paste (Al-P)

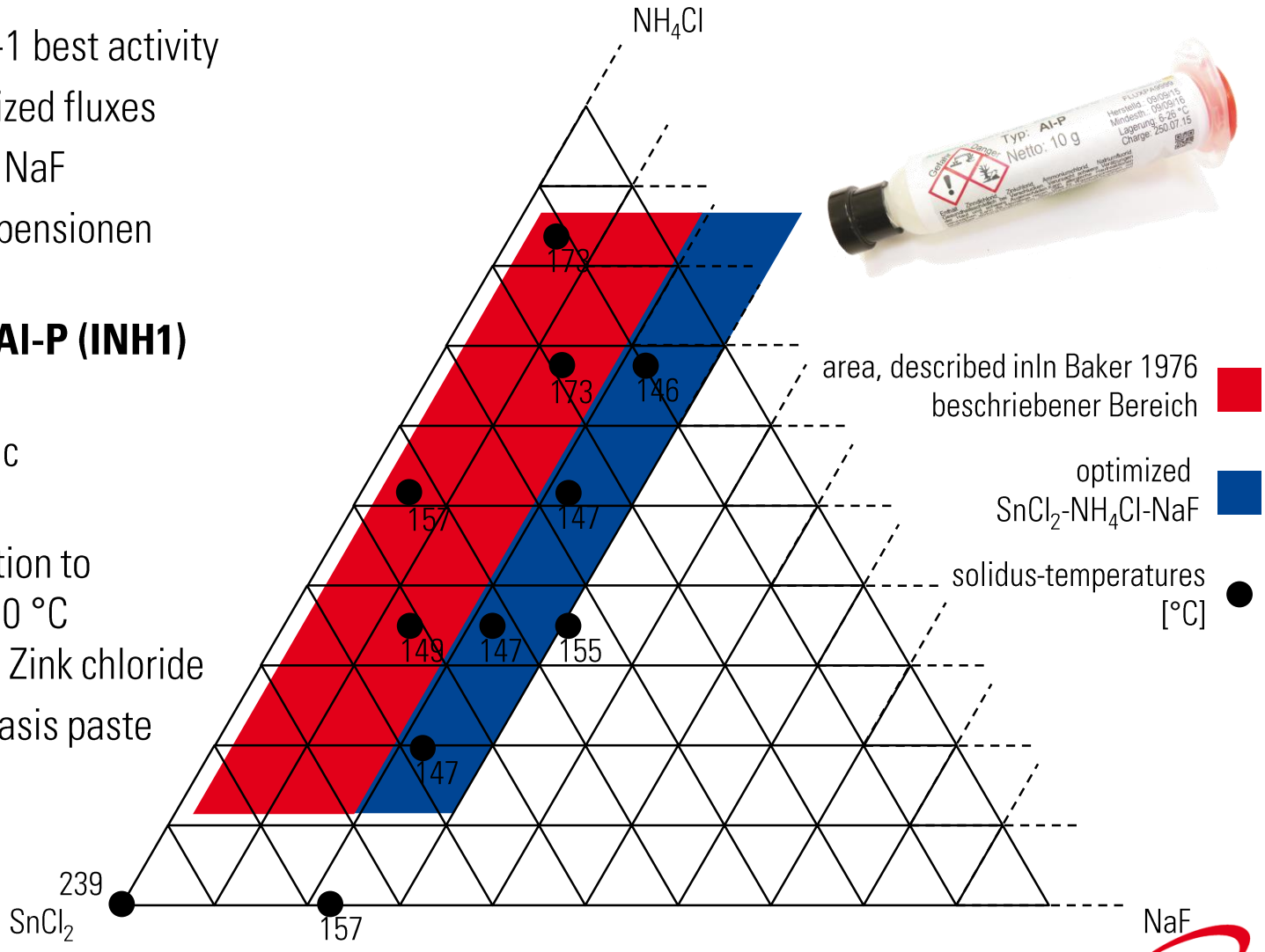
Development of rosin-based flux (ROH1)

- Improved protection against corrosion
- Solid flux for flux cored solder wires (Al-S) and (based on same composition) as liquid flux (Al-L)

Development of Al-P (INH1)

- Down 1957: F-SW-1 best activity
- Baker 1976: optimized fluxes
  - $SnCl_2$, NH_4Cl, NaF
  - Powder / Suspensionen

- **Development of Al-P (INH1)**
  - systematic thermoanalytic investigation
  - Further reduction to lower than 130 °C by addition of Zink chloride
  - Use of inert basis paste

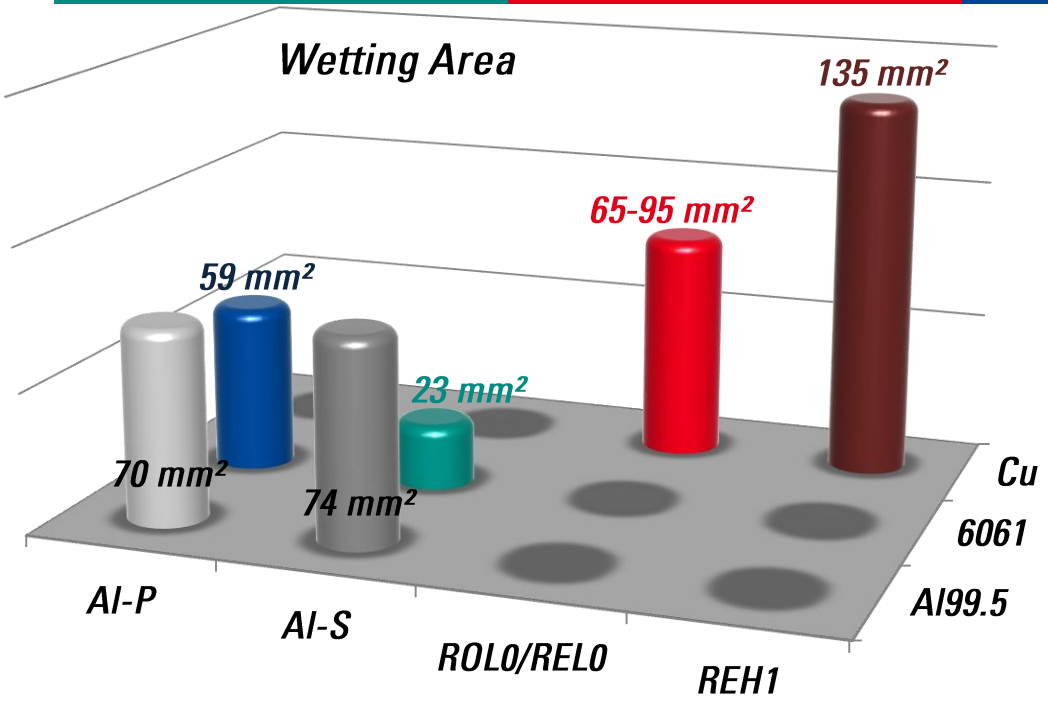


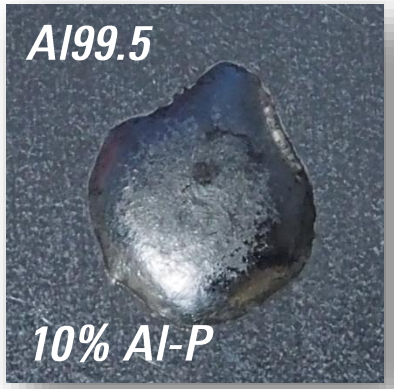
Development of Al-S/Al-L (ROH1)

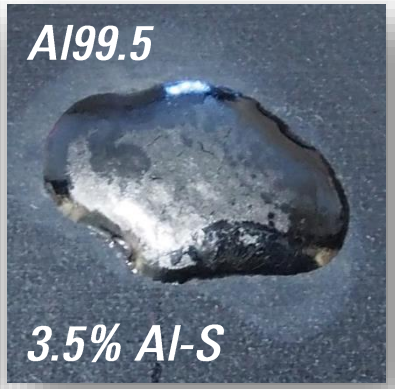
- Well known encapsulating and protective effect of rosin on flux residues
- Miwa 1972: Aluminum flux with improved protection against corrosion
  - Curable epoxy resin & rosin
  - Heavy metal fluoroborates & triethanolamine
  - Usable as 2-component-system only,
    due to reactions of fluoroborates and rosin/resin

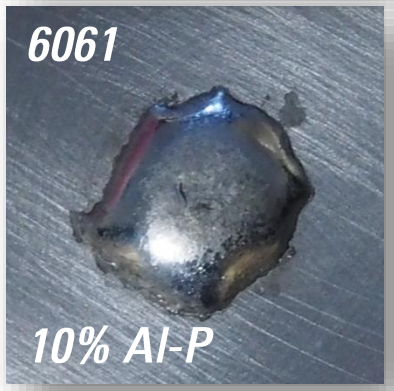
- **Development of Al-S/Al-L (ROH1)**
  - Basis: modified colophony
  - Activator: ammonium hydrogen difluoride
  - Special additives and production process
    to prevent inadequate reaction

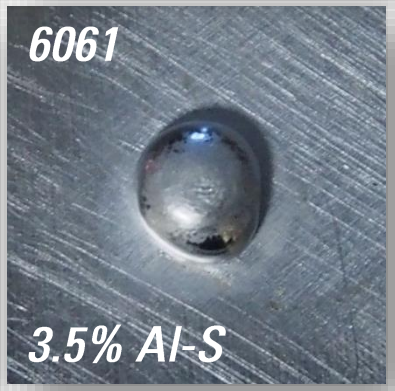
Wetting

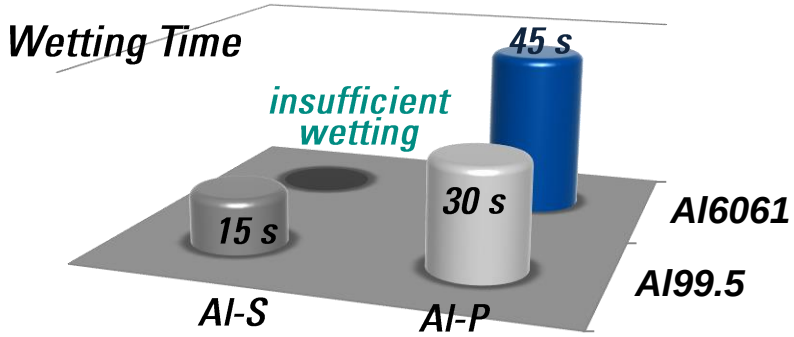












- Solder: 0.4 g SAC305 combined with:
  - 10 % Al-P INH1 Flux Paste
  - 3.5% Al-S ROH1 Solid Flux
- Substrate: Al99.5 and 6061 (AlMg1SiCu)
- Soldering Temperature: 252 °C

Wetting

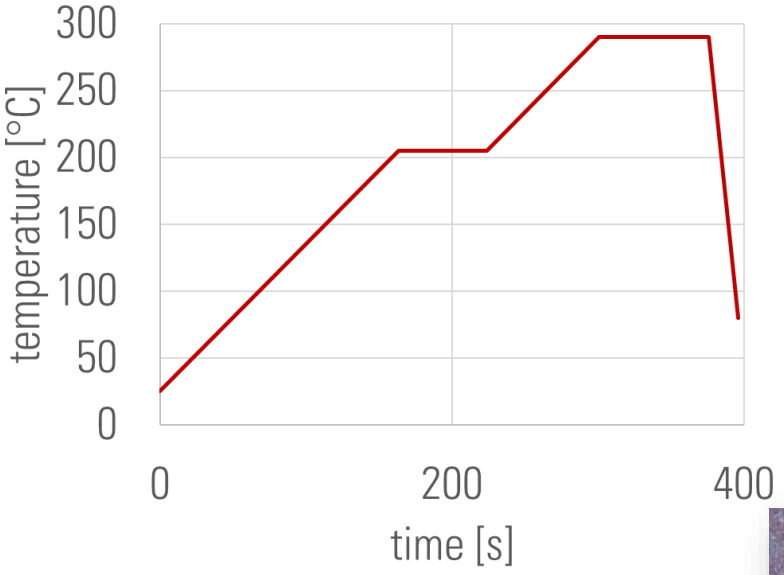
On pure Aluminum

- Good wetting with flux paste Al-P and flux cored wire Al-S
  - Wetting angle < 30 °
  - Similar to wetting with low activated flux on Copper ➔ requirements of industrial joining processes are fulfilled generally
- Wetting slightly faster with Al-S than with Al-P
  - Solder forming reaction between flux Al-P and Aluminum needs more time than just oxide removing effect of fluoride activated rosin flux Al-S
  - But: application as paste ➔ use in e.g. reflow processes
    ➔ More time requirement is less critical than for iron soldering with cored wire

On alloy 6061

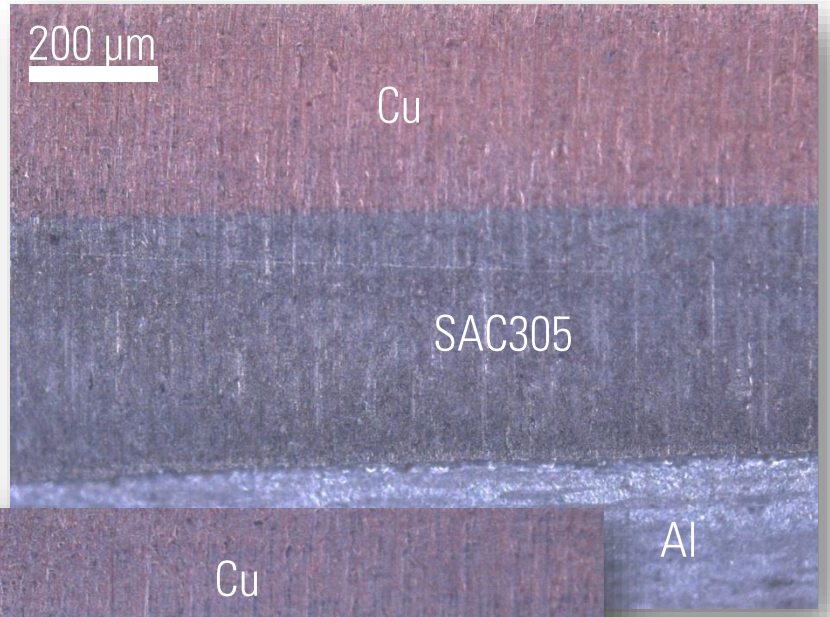
- Stable oxide layer due to Magnesium ➔ High activity required
- Advantage of solder forming flux Al-P
- Still good wetting (< 30 °), but increased wetting time
- Al-S not suitable

Reflow Soldering

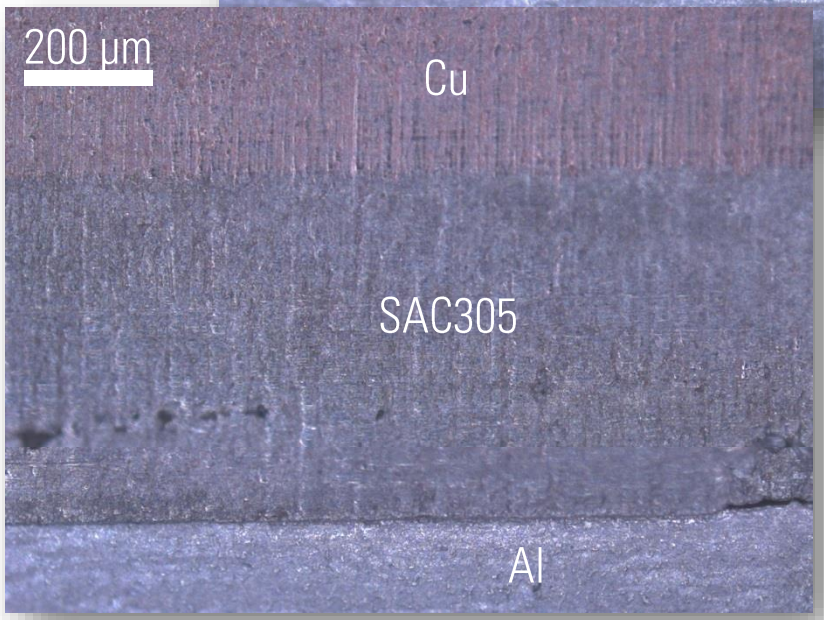


- Pure Copper to pure Aluminum
- SAC305
- Al-P (INH1, as flux paste + solid wire)
- Al-S (ROH1, as cored wire)
- Reflow

Al-P



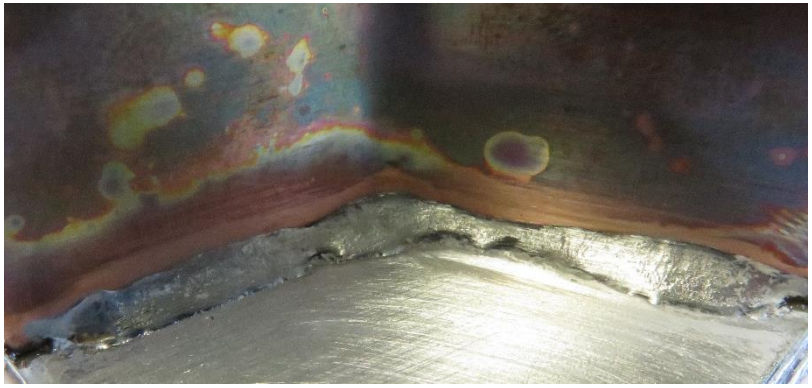
Al-S

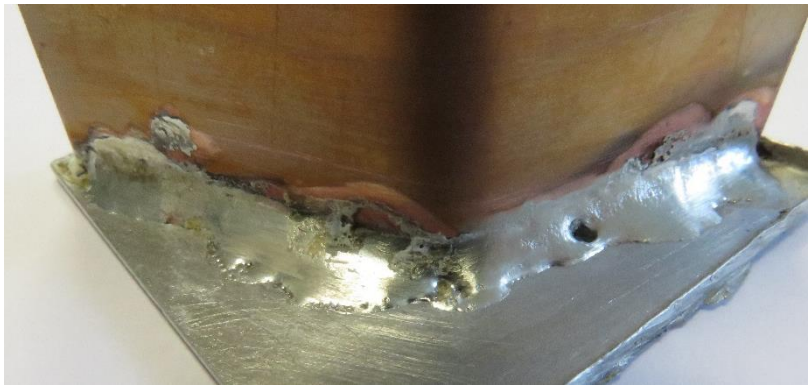


Flame soldering of Structural Components

- Pure Copper to pure Aluminum // SAC305
- Al-S (ROH1, as cored wire): indirect flame heating
- Al-P (INH1, as flux paste + solid wire) direct flame heating

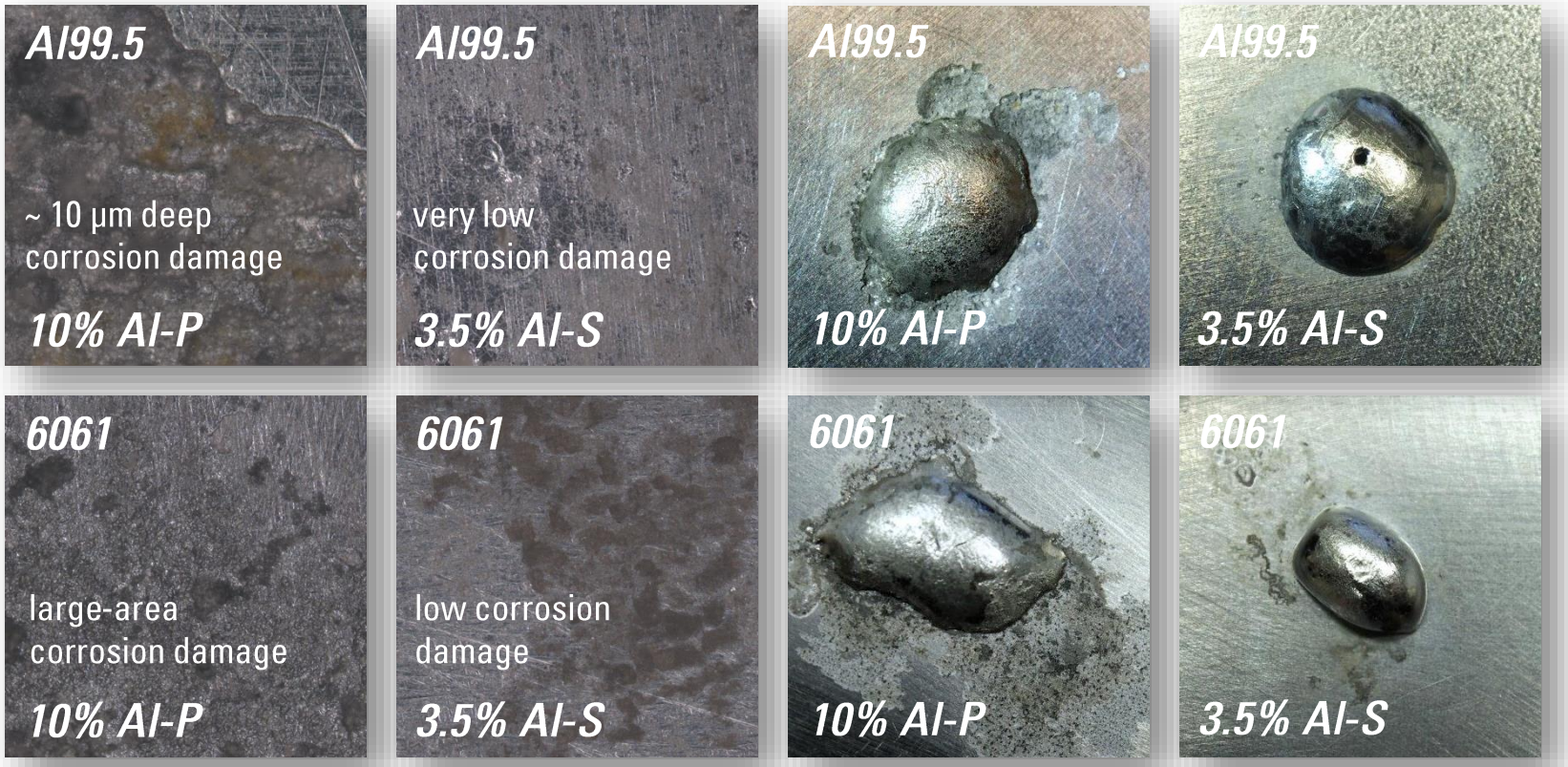
Al-S





Al-P

Corrosion Behavior



- Corrosion of wetting speciemen. SAC305 combined with 10 % Al-P and 3.5% Al-S on Al99.5 and 6061; tested as soldered without cleaning, 7 days, 40 °C and 93% r. H.; cleaned after corrosion test
- **Cleaning necessary for INH1/F-SW-1** flux paste Al-P
- **Cleaning suggested for ROH1** flux Al-S, but significantly **less critical**.

Conclusion & Outlook

- Aluminum can be soldered by use of ROH1 and INH1 fluxes
- Both Al-Al and Al-Cu joints are possible
- INH1 fluxes offer highest activity, also for soldering of Al alloys, available as flux paste Al-P
- ROH1 fluxes offer lower risk of corrosion by protection layer of rosin, available as solid flux Al-S for flux cored solder wires and liquid flux Al-L
- Different soldering processes for bigger structures were done successful
- Outlook: Adaption to micro level. E.g. soldering of pcb with Al conductive paths. Parallel development of optimized fluxes and Al components, supporting each other?!