SOLDERING OF ALUMINUM WITH ROSIN BASED AND INORGANIC FLUXES

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TAMURA ELSOLD: The full range of soldering materials

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

TAMURA Corp.

Electronic components
Electronic Chemicals & FA Systems
Information Equipment

- Solder Pastes
- Solder Fluxes
- Solder Resists
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1906</td>
<td>Bleiwerke Goslar</td>
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<tr>
<td>1954</td>
<td>Trademark ELSOLD arises, Production of solder products</td>
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<tr>
<td>2010</td>
<td>ELSOLD GmbH &amp; Co. KG becomes subsidiary of JL Goslar</td>
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<td>2013</td>
<td>Opening of new facility in Ilsenburg on a 5,000 m² site with 1,350 m² production area and 320 m² office space</td>
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<td>1924</td>
<td>Foundation of Tamura Radio Trading Comp.</td>
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<td>1956</td>
<td>First Tamura Solderite Flux</td>
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<td>1960s-1980s</td>
<td>First Tamura Masks and Solder Pastes</td>
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<td>2017</td>
<td>ELSOLD becomes new member of TAMURA Corp.</td>
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<tr>
<td>2018</td>
<td>TAMURA ELSOLD GmbH</td>
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**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

![Graph comparing Density, Conductivity, Specific Conductivity, and Price of Aluminum and Copper](image-url)
MOTIVATION: PRICE OF ALUMINUM VS COPPER

Development of Prices 2009-2018
Price May 2018 | Copper: 5850 €/t | Aluminum: 1941 €/t

[BOERSE ONLINE]
Motivation: Reasons for Use of Aluminum Cables

- Stable price
- Reduced theft risk
- Easy handling
- High flexibility
- Light weight
- Low costs
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.

- **Applicability:**
  - 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 (AI-P)

Development of rosin-based flux (ROH1)
- Improved protection against corrosion
- Solid flux for flux cored solder wires (AI-S) and (based on same composition) as liquid flux (AI-L)
**Development of Al-P (INH1)**

- Down 1957: F-SW-1 best activity
- Baker 1976: optimized fluxes
  - SnCl$_2$, NH$_4$Cl, 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
- AI-P (INH1, as flux paste + solid wire)
- AI-S (ROH1, as cored wire)
- Reflow
**FLAME SOLDERING OF STRUCTURAL COMPONENTS**

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

- Corrosion of wetting specimen. 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?!