PRESENTATION OF PROJECT CONSORTIUM

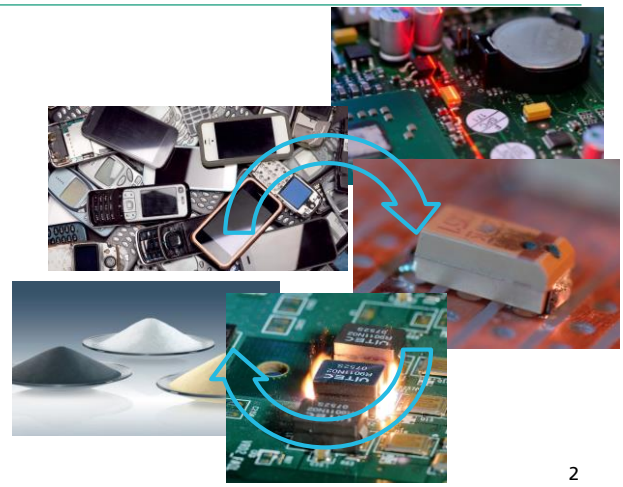
ADIR Demo Day – Top 4

Goslar, May 17, 2019

Fraunhofer ILT

CONSORTIUM OVERVIEW

- Electrocycling GmbH – ECG
- Fraunhofer-Institute for Laser Technology – ILT
- Laser Analytical Systems & Automation – LSA
- Osai A.S. S.p.A. – OS
- TAU Industrial Robotics – TRT
- Institute of Non-ferrous Metals – IMN
- Aurubis – AU
- H.C. Starck Tantalum and Niobium GmbH – HTN



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ADIR

LSA Osai TAU Aurubis H.C.Starck Tantalum & Niobium IMN ELECTRO CYCLING

Fraunhofer ILT

ELECTRO CYCLING

Maik Bergamos

- Founded in 1994
- Certified recycler for electrical and electronic equipment.
- Currently 210 employees
- Environmentally conscious electrical recycling for all requirements
- Processing of 80.000 t E-scrap per year

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Tasks of ECG within the project

- **Procurement of Material for process development**

  15,000 Mobile phones and 1,600 Server-PCBs collected within the project time

- **Development and provision of machine assembly for material feed**
- **Provision of installation area for demonstrator on site of ECG**

- **Conduction of Field tests**

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ELECTRO CYCLING

Project work / results

- Conduction of Field tests

Output of ADIR Demonstrator Process:

1 kg MPH-PCBs = ~94 g ICs	1 kg Server-PCBs = ~10,5 g ICs
~38g Ta-Caps	~4.5 g Ta-Caps
~19 g SAW-filter	~1.5 g SAW-filter

Outlook / perspectives

- Extension of list for material input

Motherboards extracted from Laptops/Notebooks

PCBs extracted from electronic control units (ECU; automotive)

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Fraunhofer Institute for Laser Technology – ILT

Reinhard Noll, Cord Fricke-Begemann, Frederik Schreckenberg

ILT

- institute for applied research, ca. 400 employees in Aachen, Germany
- know-how in technologies and processes for industrial laser applications
- development of laser measurement system, set-up of prototypes

ADIR

- coordination of project consortium
- laser-based inspection system
- laser desoldering processes
- technology for electrohydraulic fragmentation

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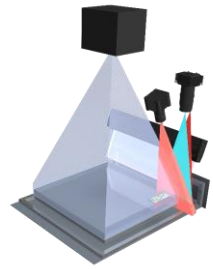
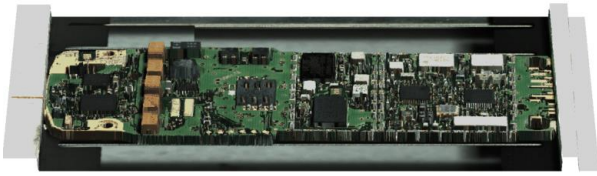
Fraunhofer Institute for Laser Technology – ILT project work

inspection machine

- high resolution imaging of PCBs
- 3D contour measurement
- component identification
- chemical inspection (LIBS)
- data base of PCB information

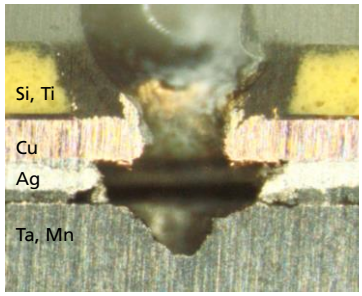


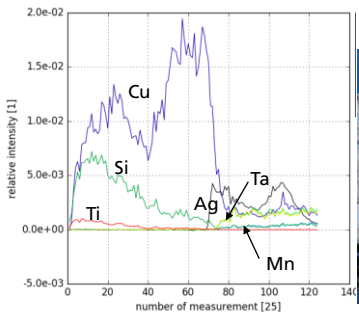


Fraunhofer Institute for Laser Technology – ILT results

laser ablation and spectroscopic analysis

content identification





electrohydraulic fragmentation by pulsed-power

separation of MPH modules

LSA GmbH

Business area

Production of automated systems for contact-less chemical analysis (inline and offline)

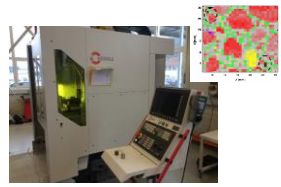
History

Founded 2004 as a spin-off company of the Fraunhofer Institute for Laser Technology (ILT), Aachen

R&D partners

Fraunhofer ILT
RWTH AACHEN UNIVERSITY
LIÈGE université

Copra - Coil mix-up detection



Silenos scanning steel analysis

Salt-A online salt/fertilizer analysis

Coal-A online coal analysis

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ADIR

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Fraunhofer ILT

MAIN TASKS OF LSA IN ADIR

- Implementation of a fully automated LIBS measuring process for the spatially resolved determination of the chemical composition of electronic components
- Control of laser, spectrometer, scanner
- Development of three interconnected software modules:
  - LIBS process control including spectrometric data acquisition and analysis (SpecControl)
  - Beam guidance control for LIBS scanning operation (Scanner-GUI)
  - GUI for manual selection of measuring points (CoordsPicker)
  - Interfacing and synchronization with 2D/3D image processing and master control

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ADIR

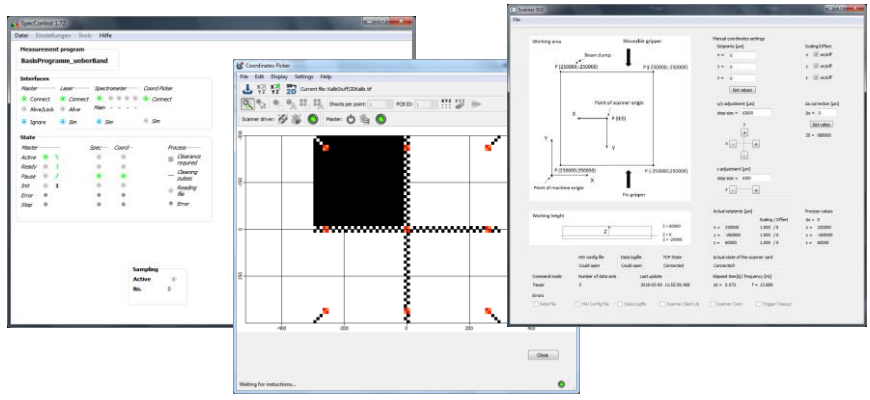
LSA Osai TAU Aurubis H.C.Starck Tantalum & Niobium RWTH ELECTRO CYCLING

Fraunhofer ILT

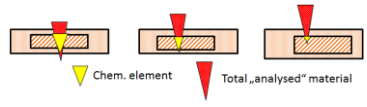
LSA GmbH
role in the consortium

Software modules

- „SpecControl“: ADIR master interface, process control, laser driver, measurement configuration
- „CoordsPicker“, coordinates selection
- „Scanner-GUI“, laser focus positioning



- Development of „Score Evaluation“: determination of the **probability**, that the analysed component contains substantial amounts of the element of interest



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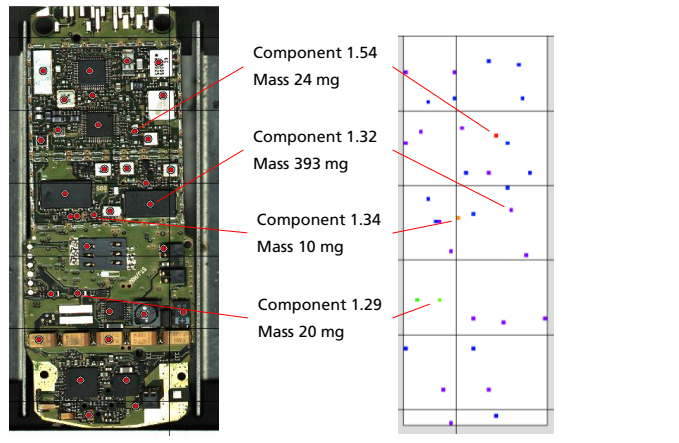
LSA GmbH
project work/results

- LIBS scores can be determined on selected sample locations for various chemical elements (e.g. Ag, Au, Pd, Nd, Nb, …)
- Refinement of LIBS parameterization for score analysis in multi-matrix environment is ongoing
- Measurement strategy for drilling/spatial resolution is adapted according to field test experience

Example: Pd scores



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OSAI A.S. spa – Alice Tori

- SME located near Torino, Italy
- Industrial automation
- System integration
- Laser material processing
- R&D department

On **november 1st 2017** has been opened a new plant of **950 sqm** **(currently 6140 sqm)**

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OSAI ROLE IN ADIR PROJECT

- Design and assembly of machine 3
  - Laser desoldering
  - Laser cutting
  - Sorting and collection of extracted components
  - Suction nozzle for the extraction of components
- Manipulator integration
- System integrator

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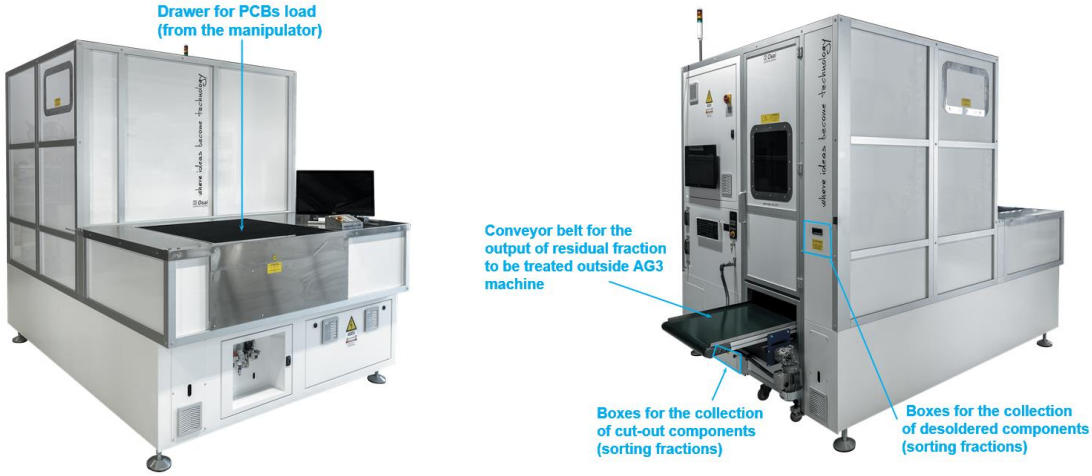
OSAI
machine 3 – extraction and sorting of components from PCBs



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TreTau Engineering S.r.l. – Filippo Veglia

- TAU is a later stage venture from Turin, Italy, focused on reinventing traditional and conservative manufacturing methods across multiple industries.
- Tau's team of 30 engineers, spread across Europe, are all passionate about innovation and changing the manufacturing industry through high tech/high performance solutions
- We have developed and patented
  - advanced polymer coating technology,
  - in-line quality control system utilizing machine vision and spectroscopy.

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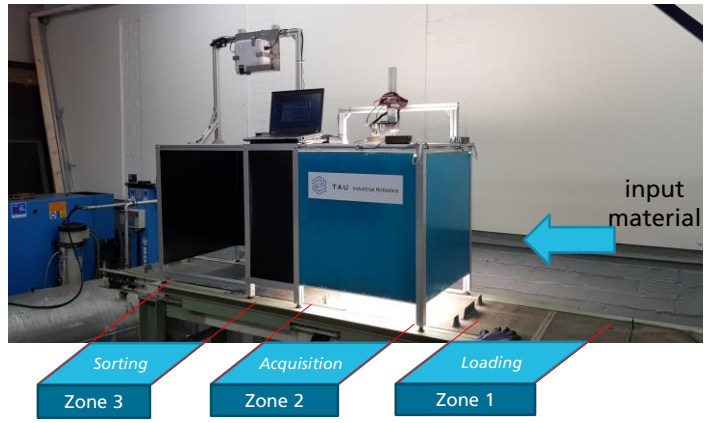
TAU Role in the ADIR Project

- Machine vision prototype using artificial intelligence to identify pieces, e.g., vibrational alerts (W, Nd)
- Imaging machine searches for pieces-of-interest (POI) in MPH residues for sorting
- 3 zones
  1. Loading area: material feeding
  2. Acquisition area: imaging of the belt and POI identification
  3. Sorting area: POI highlighting for manual pick-up.
- Future extension to automated sorting possible

TAU Machine Vision System at ECG



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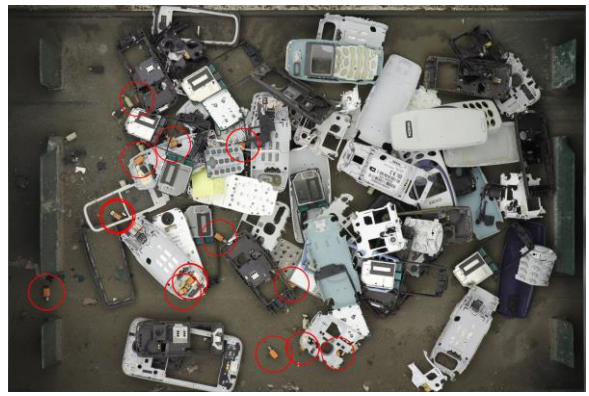
Loading and Acquisition (Zone 1 and Zone 2)

Load Zone 1 and
move material to Zone 2



Take a picture of the material in Zone 2 and identify pieces using AI

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Sorting of the material (Zone 3)

The identified pieces are moved by the conveyor into the sorting area

Identified pieces are highlighted in Zone 3 for manual pick-up.

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Institute for non-ferrous metallurgy – IMN, Michal Drzazga

Instytut Metali Nieżelaznych Gliwice

SIEĆ BADAWCZA ŁUKASIEWICZ

- state-owned institute
- one of the largest research institutes in Poland, Gliwice
- the main research centre of the non-ferrous industry, especially Cu, Al, Zn, Pb
- over 500 employes
- complex studies conducted in 14 research departments

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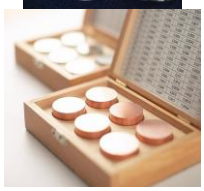
Institute for non-ferrous metallurgy – IMN

Instytut Metali Nieżelaznych Gliwice

SIEĆ BADAWCZA ŁUKASIEWICZ

PCA Polskie Centrum Akredytacji BADANIA AB 073



- Studies of all non-ferrous metals, especially Cu, Al, Zn, Pb
- Certified laboratories
- From laboratory to industrial tests, implementation, experimental production, technical services and consulting
- Close cooperation with industry

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IMN in the ADIR project

- **Preliminary screening analyses** of mobile phones and server boards by the XRF method - the first input data for the machine and determination of the recovered fraction
- **Tests of manually obtained fractions** – preparation of fractions manually, analytical studies and preliminary recovery attempts
- Development of technologies for **precious metals recovery** from components fraction – recovery of Au, Ag and PGM
- Development of technologies for **Nd recovery** from mobile phone speakers
- Development of **analytical procedures** for all stages of the recovery technologies
- Additional actions for **analytical data** obtaining – „cherry picking" experiments, PCB subclasses etc.
- **Validation of the process** – analyses of the fractions separated by the machine and using them in recovery tests

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Aurubis AG – Dr. Marcus Eschen

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AURUBIS interests in the ADIR project

- AURUBIS is **investigating the recovery of** so-called **"strategic metals"** which are not already covered in the current flow sheet. The results of the research project will be an important part of the implementation process.
- AURUBIS has **a lot of information to e-scrap** and also total material flow in the recycling chain:
  - Screening of materials
  - Working on the fundamentals of recoveries
  - Sampling, homogenizing and chemical analysis of the investigated materials and products.
- AURUBIS is **working on sorting technologies** and also criteria:
  - Know how and well contacts to the experienced companies
  - Integration into existing flow sheets of material sorting
  - Considering extraction possibilities: The whole recovery process.
- AURUBIS is also **interested in the expanding on the recycling of high-value devices** by using new detection and sorting technologies in order to increase the added value.

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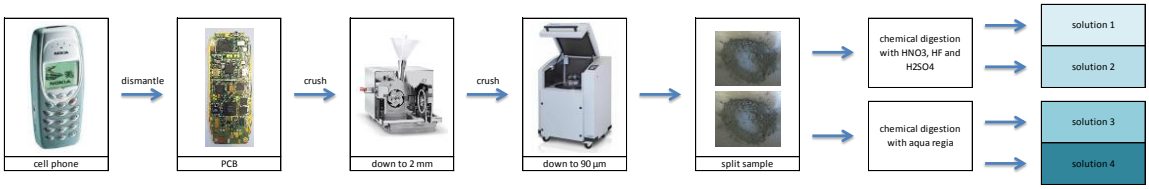
Aurubis AG
role in the consortium

- **Chemical analysis and material characterization of input materials and output residual fractions**
  - Task 2.2: Chemical analysis (of whole MPHs)
  - Task 3.6: Metallurgical treatment of selected components with valuable materials
  - Task 6.4: Recovery of valuable materials based on the sorted fractions (from ADIR demonstrator)
- **Pyro and Hydro metallurgical test works (lab scale) for process route evaluation and definition / Provision of test materials**
  - Task 4.4: Metallurgical characterization of pre-treated components
- **Data evaluation and assessment of the ADIR process**
  - Task 7.2: Assessment of the sorted fractions and recovered valuable materials
  - Task 7.3: Assessment of technical and economic performance, scalability

Aurubis AG
project work/results

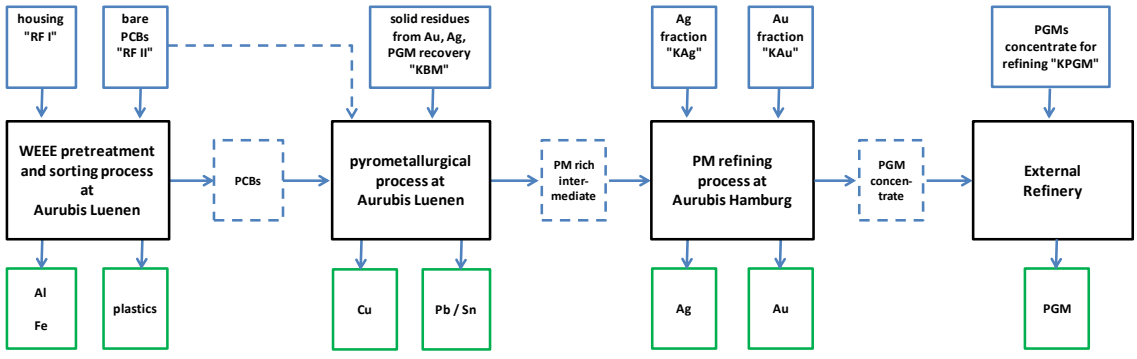
- **Investigations on single MPHs by dismantling and crushing followed by wet analytics**



- **Investigations on PCBs without sample preparation by elemental mapping with 2D µ-XRF**

Aurubis AG
project work/results

- The recovery of valuable metals from all residual fractions coming from the ADIR process can be done at Aurubis using the implemented industrial standard processes at the Aurubis plants in Lünen and Hamburg

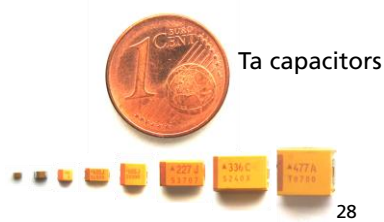


H.C. Starck Tantalum & Niobium GmbH – H. Brumm

- Leading market producer of high-quality tantalum- and niobium-based materials with over 60 years' experience
- One of the broadest tantalum product portfolios on the market including: powders for capacitors and sputter targets, high-purity oxides, other specialty compounds like hydroxides, chlorides, oxalates, powders for additive manufacturing and alloy additives
- Four production facilities in Germany, Japan and Thailand and 660 employees worldwide
- Products facilitating megatrends like the IoT (Internet of Things), AI (Artificial Intelligence), smart factories, E-Mobility, vehicle-to-vehicle communication, or 3D Printing

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt									

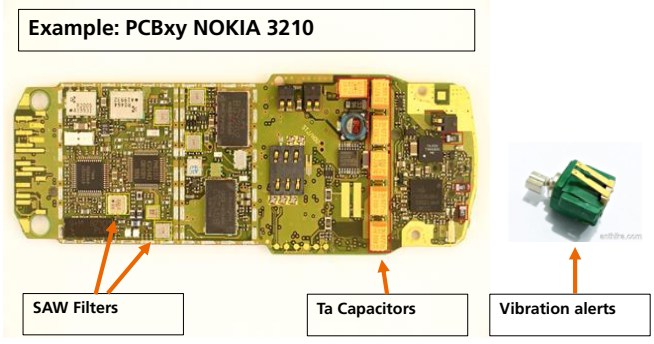
HCS Ta&Nb core material | New business development | Metal



Ta capacitors

H.C. Starck Tantalum & Niobium GmbH role in the consortium

- identify valuable electronic components from boards for recycling of Tantalum (Ta), Niobium (Nb) and Tungsten (W)



Tantalum (Ta) :
- Tantalum Capacitors
- SAW Filters

Tungsten (W)
- Vibration alerts

- confirm existing recycling processes for the identified components or develop new processes
- economical assessment after field test of ADIR demonstrator

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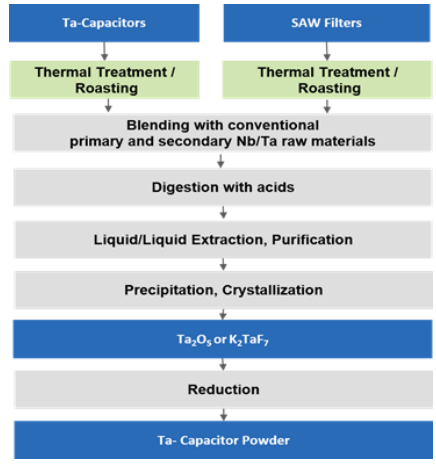
H.C. Starck Tantalum & Niobium GmbH Recovery of Tantalum from Capacitors and SAW Filters

Tantalum from fractions of de-soldered Ta capacitors as well as SAW filters can be recovered according to the given flow sheet.

- first step is a calcination at >1000°C to oxidize all remaining metal and plastic parts followed by a digestion in acid.
- as still significant amounts of impurities are in solution, an additional Liquid/Liquid extraction step for removal of all impurities is essential.
- after this purification, the further manufacturing of Ta capacitor powders, i.e. crystallization and reduction, is according established state-of-the-art processes.



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Thank you for your attention