ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# Laser for E-mobility at the University of Bologna

**Erica Liverani**
Department of Industrial Engineering (DIN)

# Staff

Prof. Luca Tomesani

Full professor and manufacturing group coordinator

Prof. Alessandro Fortunato

Associate professor and research group coordinator

Ph.D ing. Alessandro Ascari

Senior assistant professor.

Main research topic: laser welding and DED

Ph.D ing. Erica Liverani

Research fellow.

Main research topic:

PBF additive manufacturing

Ph.D ing. Antonio Candido

Research fellow.

Main research topic: data science, modeling, machine learning for manufacturing

M.Sc Lorenzo Cestone

Ph.D student.

Main research topic: Optimization of grinding process for hard magnetic materials

M.Sc Paolo Ferrucci

Research fellow.

Main research topic: Direct Energy Deposition

M.Sc Edoardo Folchitto

Research fellow.

Main research topic: PBF additive manufacturing

M.Sc Hambal Iqbal

Ph.D student.

Main research topic: the wire-arc additive manufacturing (WAAM) in fabrication of metallic components

M.Sc Eriel Pérez Zapico

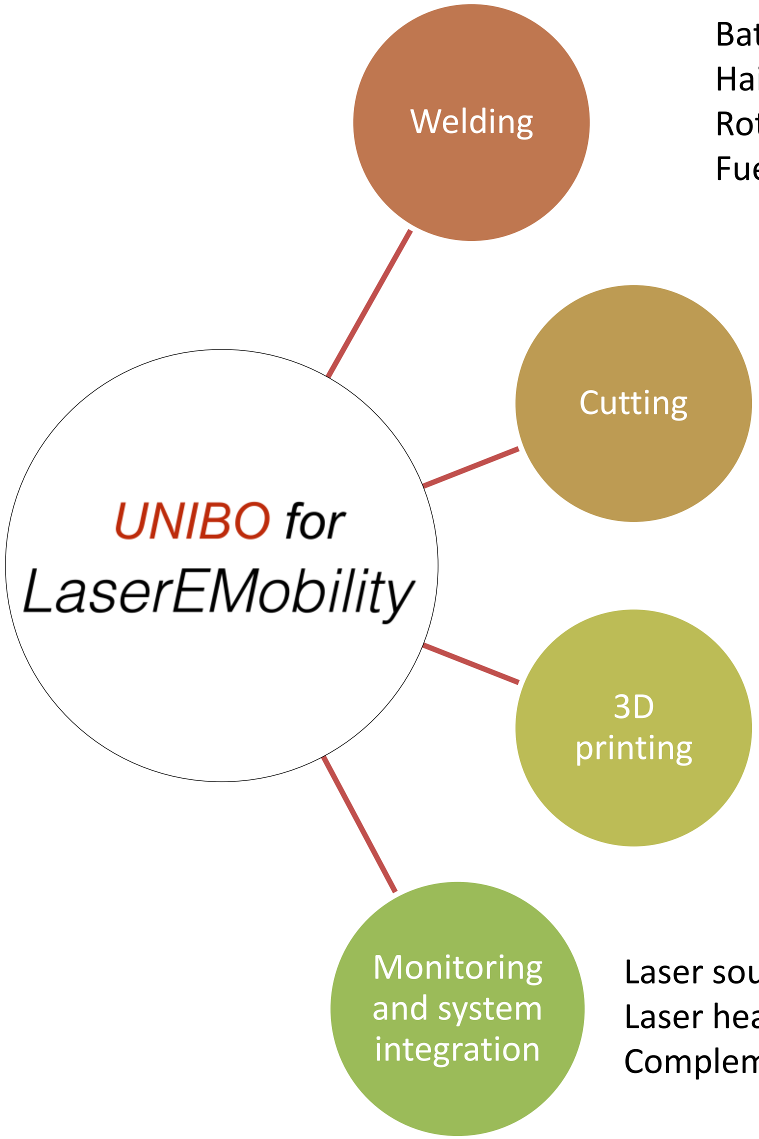
Ph.D student.

Main research topic: laser welding for electric automotive components

# Gruppo Laser: equipment and research activities

- 3 kW CW Laserline **diode laser** (1000 μm delivery fiber core diameter)
- 1.5 kW CW Laserline diode laser **blu laser**
- 6 kW **CW** IPG YLS Yb:**fiber laser** (50 μm delivery fiber core diameter)
- 3 kW CW nLight  Yb:fiber laser (50 μm delivery fiber core diameter)
- 1 kW CW nLight **single mode** fiber laser (50 μm delivery fiber core diameter)
- 1 kW CW Trumpf Nd:YAG laser (300 μm delivery fiber core diameter)
- 300-3000 W **Q-CW** long pulse Yb:fiber IPG laser (50 μm delivery fiber core diameter)
- 200 W **long pulse** Nd:YAG Trumpf laser (400 μm delivery fiber core diameter)
- 20 W **short pulse** Yb:fiber IPG laser
- 7 W **ultra-short pulse** Ti:Sapphire Light Conversion laser
- GTV 2 hoppers powder feeder + GTV 6-ways powder nozzle
- 6 axes anthropomorphic robot + 1 axis rotary positioner
- Several fixed focal and galvo focusing heads
- Sisma **Mysint 100 LPBF** 3D printing machine

# Research activities for E-mobility




**Welding**
- Battery Tray welding
- Hairpin welding
- Rotor and stator welding
- Fuel Battery welding

**Cutting**
- Anode and Cathode high speed cutting

**3D printing**
- Cooling system
- Ferrosilicon rotor
- Copper components

**Monitoring and system integration**
- Laser source
- Laser head
- Complementary equipment

# Production Systems for e-mobility: welding

Applied research activities → Laboratory samples (concept validation) → Products (application validation) → Production lines (prototype and monitoring) *

Fundamental research activities

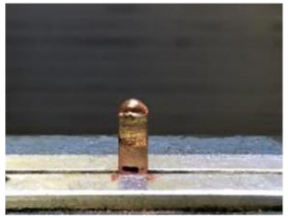
Training *

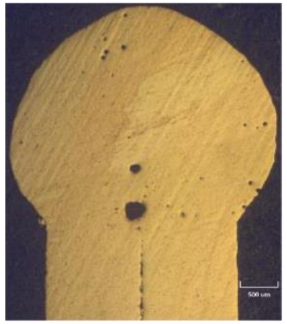
Hairpins welding

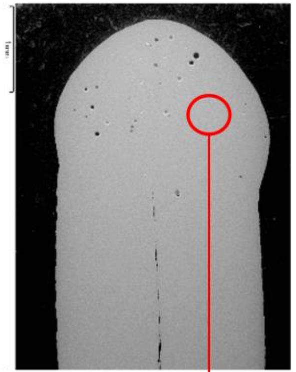
Welding of electrodes, busbar and battery case

Aims:

Process investigation and optimization



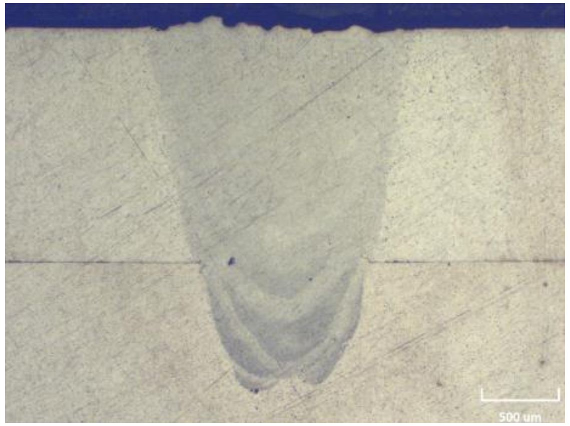




| Spectrum 2 | Wt% | Wt% Sigma | Atomic % |
|---|---|---|---|
| O | 0.52 | 0.09 | 2.04 |
| Cu | 99.48 | 0.09 | 97.96 |
| Total | 100.00 | | 100.00 |


Pouch batteries: Cu 0,3 mm – Al 0,45 mm

- Mechanical strenght: 100-130kg
- Electrical resistance: 20-40 $\mu\Omega$



Battery case: Al 6082 1,5 mm – Al6082 4 mm

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# Production Systems for e-mobility: welding for battery case

Applied research activities → Laboratory samples (concept validation) * → Products (application validation) → Production lines (prototype and monitoring) → Training

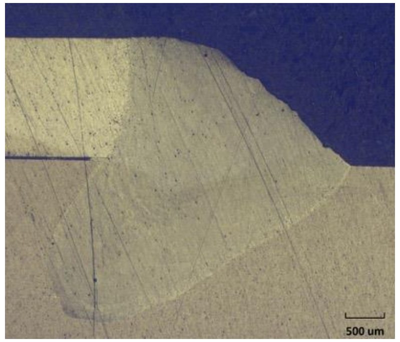
Fundamental research activities

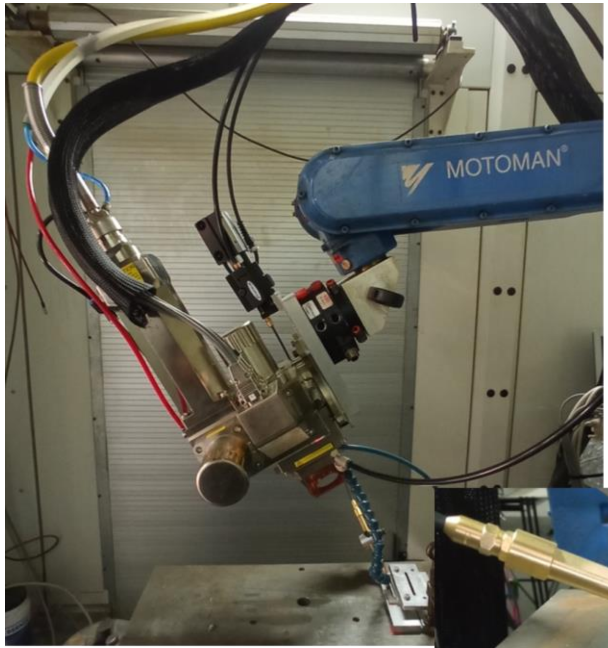
During process investigation and optimization we usually use different approach and different process.

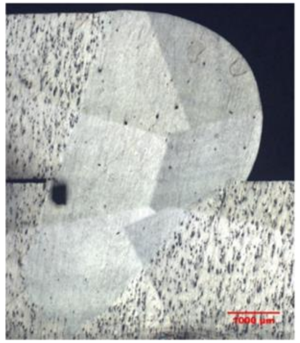
Example: LASER WELDING WITH OR WITHOUT FILLER WIRE for battery case.

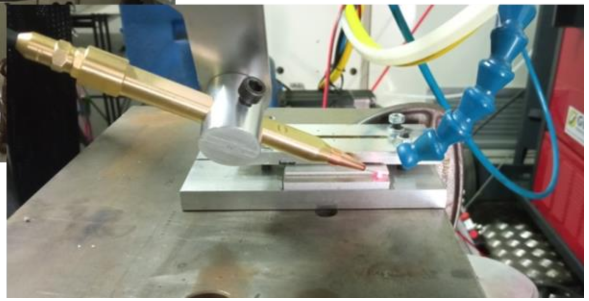
Aims:

- Metallurgy control for crack susceptibility
- Misalignment and gap control
- Low heat input and low dilution between filler and base metal.





# Production Systems for e-mobility: welding

Applied research activities → Laboratory samples (concept validation) → Products (application validation) → Production lines (prototype and monitoring) *

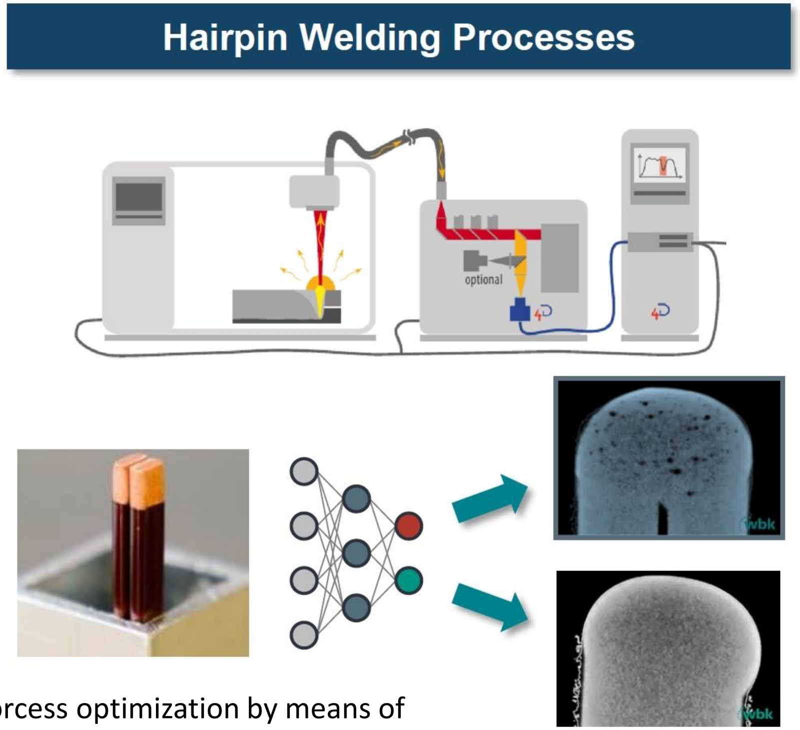
Fundamental research activities

Training *

Aims:

- Scale-up of knowledge from simple sample to real product geometries
- Optimization made by design of experiment or by means of machine learning

Porcess optimization by means of DOE




Porcess optimization by means of neural networks

Ref: Wirth & Fleischer 2019

# Production Systems for e-mobility: welding

Applied research activities → Laboratory samples (concept validation) → Products (application validation) → Production lines (prototype and monitoring) *

Fundamental research activities

→ Training *

INTEGRATION OF COMMERCIAL SYSTEMS

| | Laser source | Laser head | Complementary equipments |
|---|---|---|---|
| Ex WELDING | • nLight 3 kW<br>• IPG 6 kW | • II – VI laser head<br>• ScanLab system<br>• Remote welding configuration | • Precitec laser welding monitoring system<br>• Wire Feeding System Fronius |
| Ex CUTTING | • nLight 1 kW single mode<br>• IPG 300 W pulsed laser | • ScanLab system<br>• Raylase system<br>• Precitec cutting head | |

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# Production Systems for e-mobility: welding activity (1)

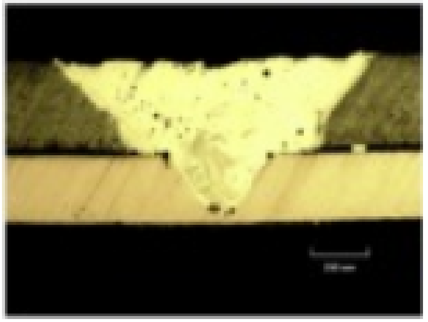
Applied research activities → Laboratory samples (concept validation) → Products (application validation) → Production lines (prototype and monitoring) *

Products (application validation) → Training *

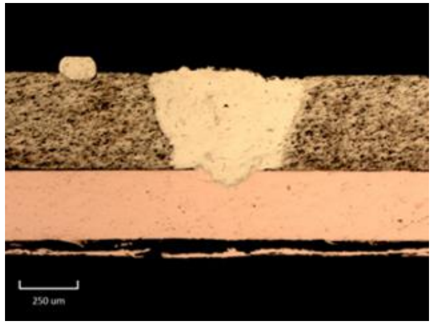
Fundamental research activities

## PULSED vs QCW vs CW

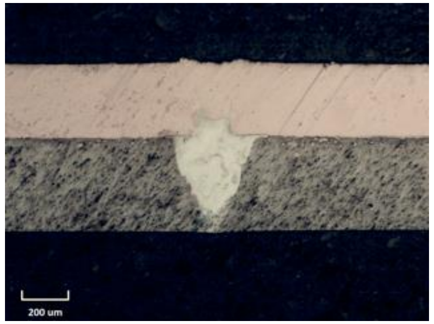
**Trumpf pulsed Nd:YAG 200 W**



**IPG QCW 300-3000**

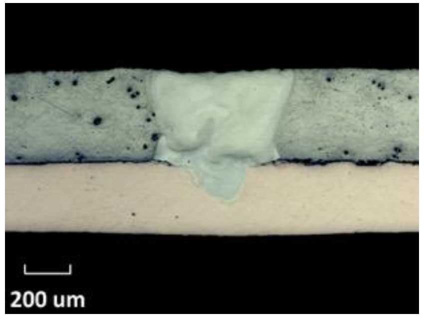


**nLight 3kW - CW**

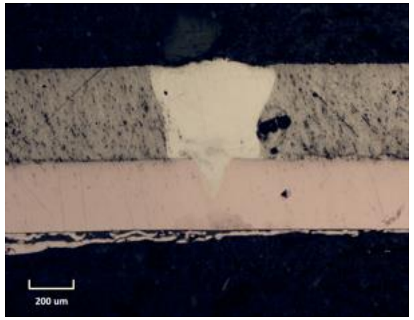


## LASER MOTION COMPARISON: linear vs wobbling

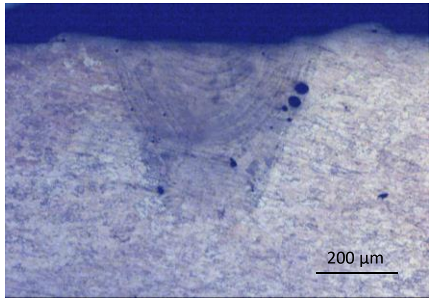
**IPG-YLR SM - Wobbling**




**IPG-YLR SM - Lineare**



## LASER SOURCE WAVELENGTH: BLU laser




ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

# Production Systems for e-mobility: welding activity (2)

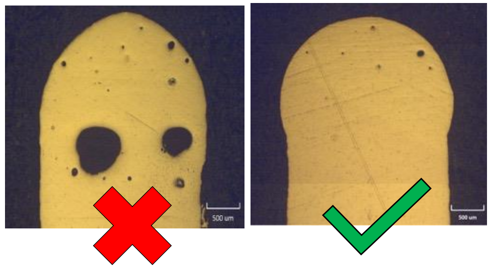
Applied research activities → Laboratory samples (concept validation) → Products (application validation) → Production lines (prototype and monitoring) *

→ Training *

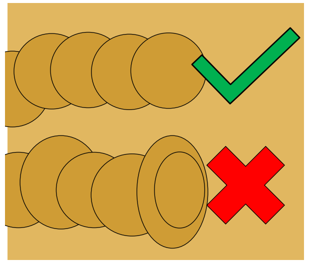
Fundamental research activities

IN-PROCESS MONITORING : TOWARDS ZERO DEFECT

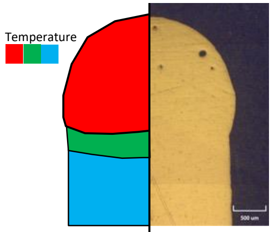
**TODAY**
RAW DATA acquisition → Data analysis → Interpretation and data collection




**TOMORROW**
RAW DATA acquisition → Data analysis → Machine Learning data elaboration → Real time detection of defects



**FUTURE TREND**
RAW DATA acquisition → DIGITAL TWIN for defect prediction



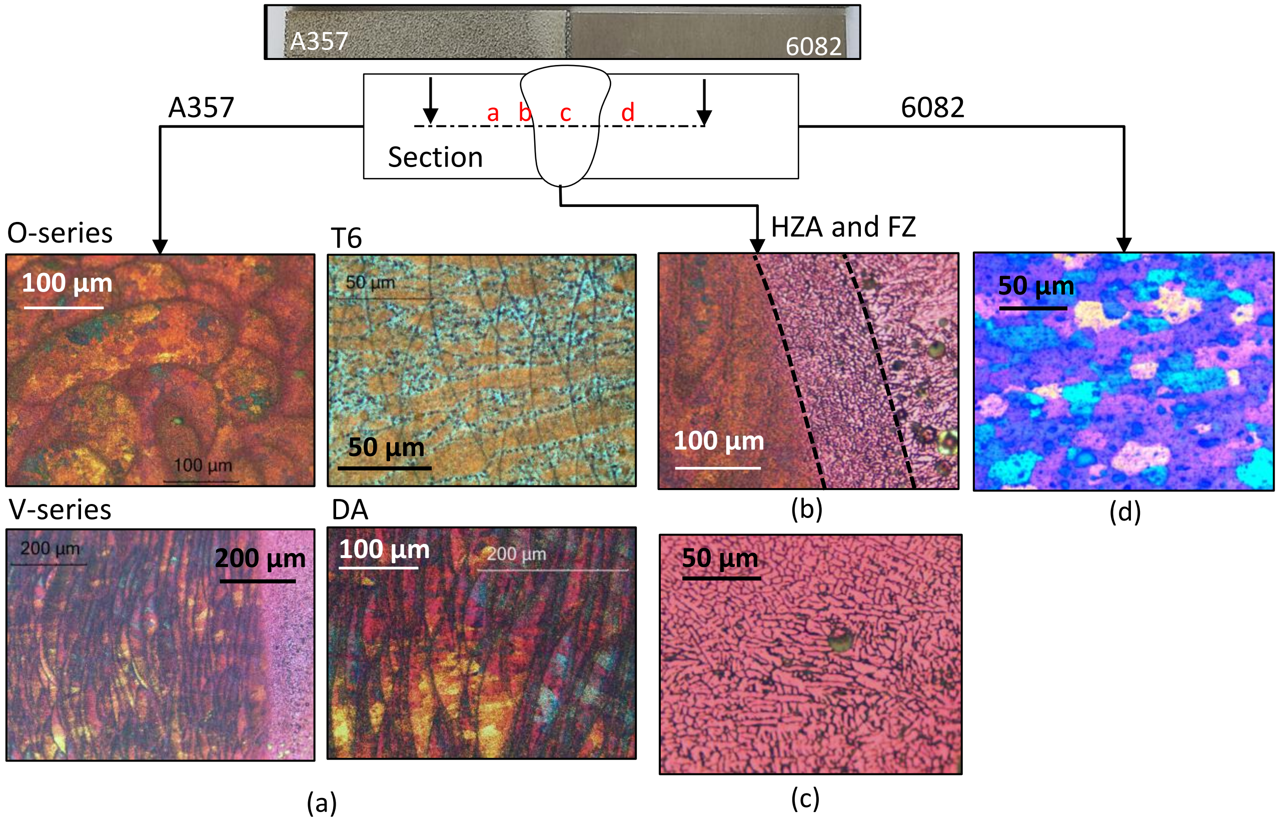

Digital twin | Experiment

# Production Systems for e-mobility: welding activity (3)

Applied research activities → Laboratory samples (concept validation) * → Products (application validation) → Production lines (prototype and monitoring) → Training

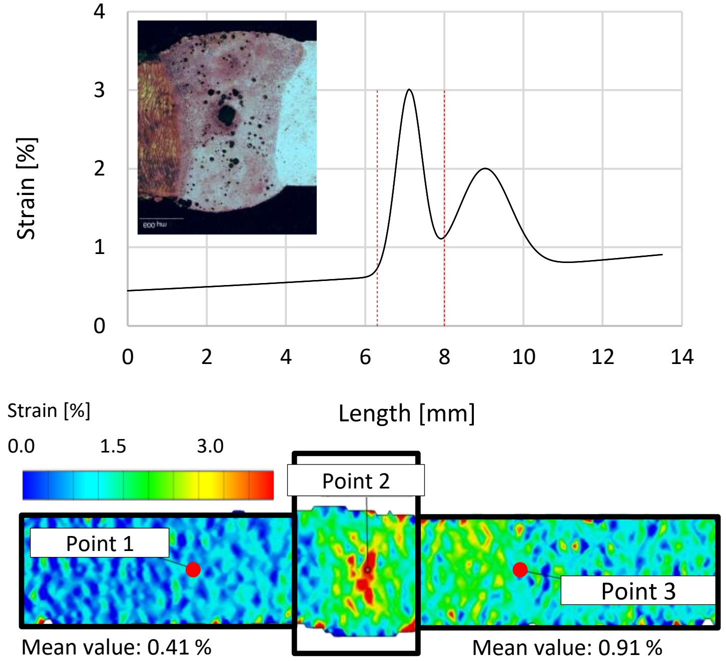
Fundamental research activities

## HYBRID MATERIAL AND HYBRID PROCESS EVALUATIONS




## Aims:

- Lightening of battery case
- Cooling optimisation



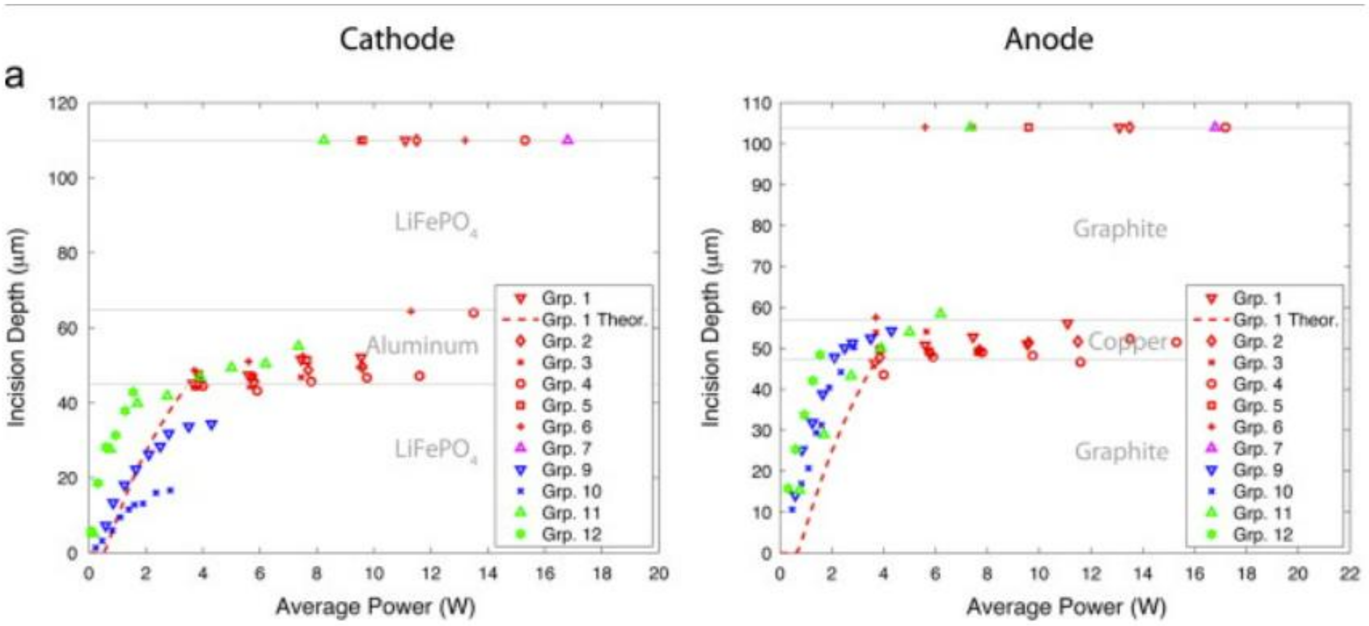
# Production Systems for e-mobility: electrodes cutting

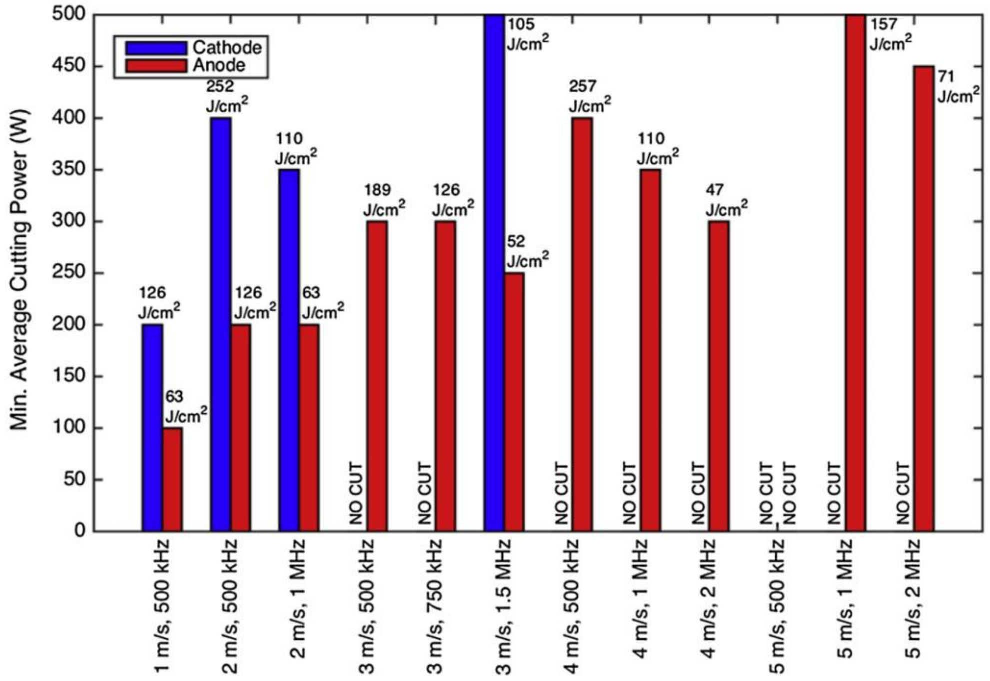
Applied research activities → Laboratory samples (concept validation) → Products (application validation) * → Production lines (prototype and monitoring)

Fundamental research activities

→ Training

Parameters optimisation and Scale-up to real electrodes cut according to the process production



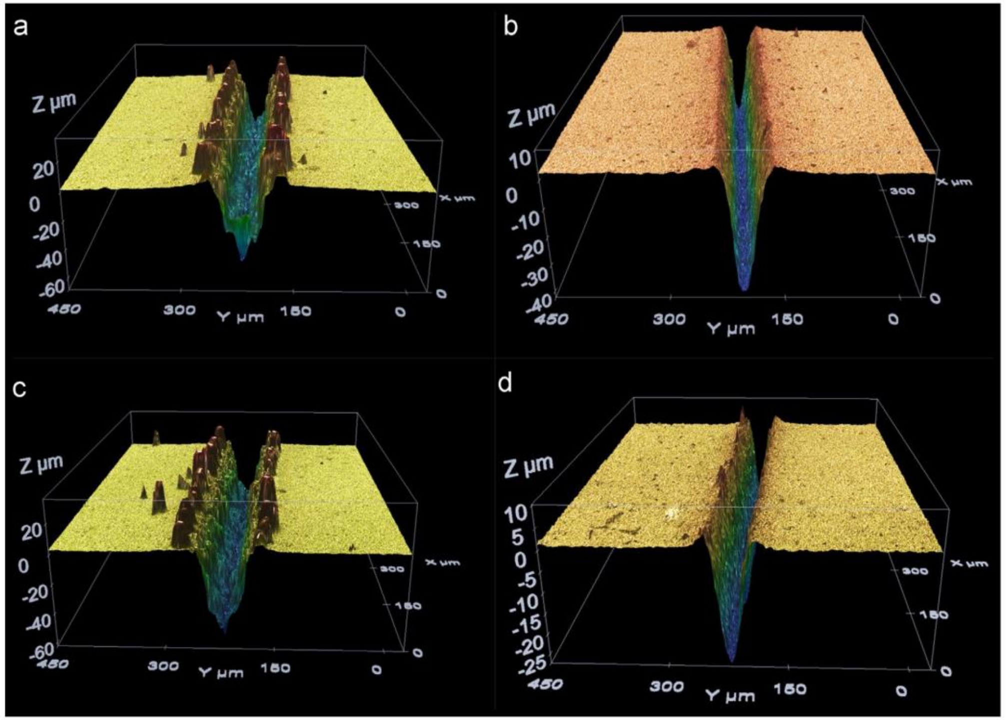
# Production Systems for e-mobility: electrodes cutting

Applied research activities → Laboratory samples (concept validation) → Products (application validation) * → Production lines (prototype and monitoring)

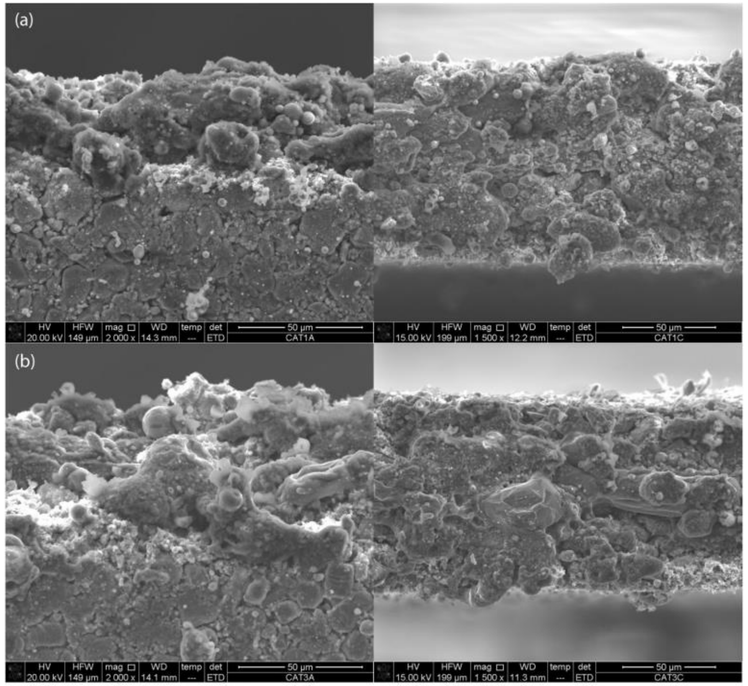
→ Training

Fundamental research activities

## In-depth analysis for process parameters/cutting quality correlations




Incision profiles for cathode as power and speed vary




Top and section SEM views of cathode cut edge following exposure at (a) 1 m=s; 500 kHz; 250 W and (b) 3 m=s; 1:5 MHz; 500 W

# Production Systems for e-mobility: additive manufacturing

Applied research activities

Fundamental research activities

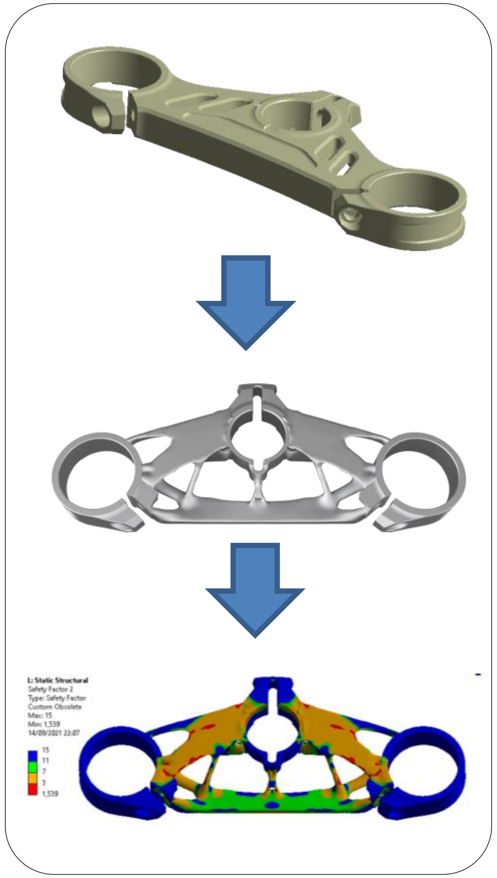
Laboratory samples (concept validation)

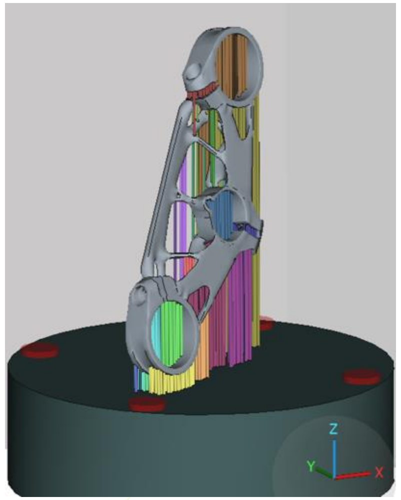
Design conceptualisation

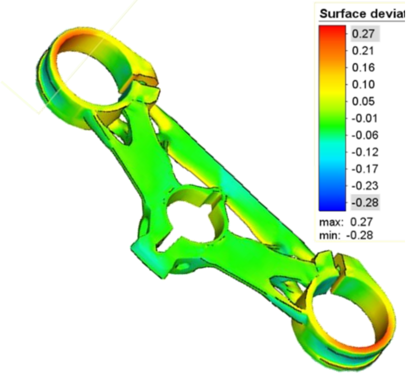
Prototype (application validation) *

Production lines (supplier identification)

Training








Aims:

- Process optimisation and scale-up of optimum parameters form simple samples to real components
- Component re-design and validation
- Supplier identification and training

# Production Systems for e-mobility: additive manufacturing

Applied research activities

Fundamental research activities

Laboratory samples (concept validation)

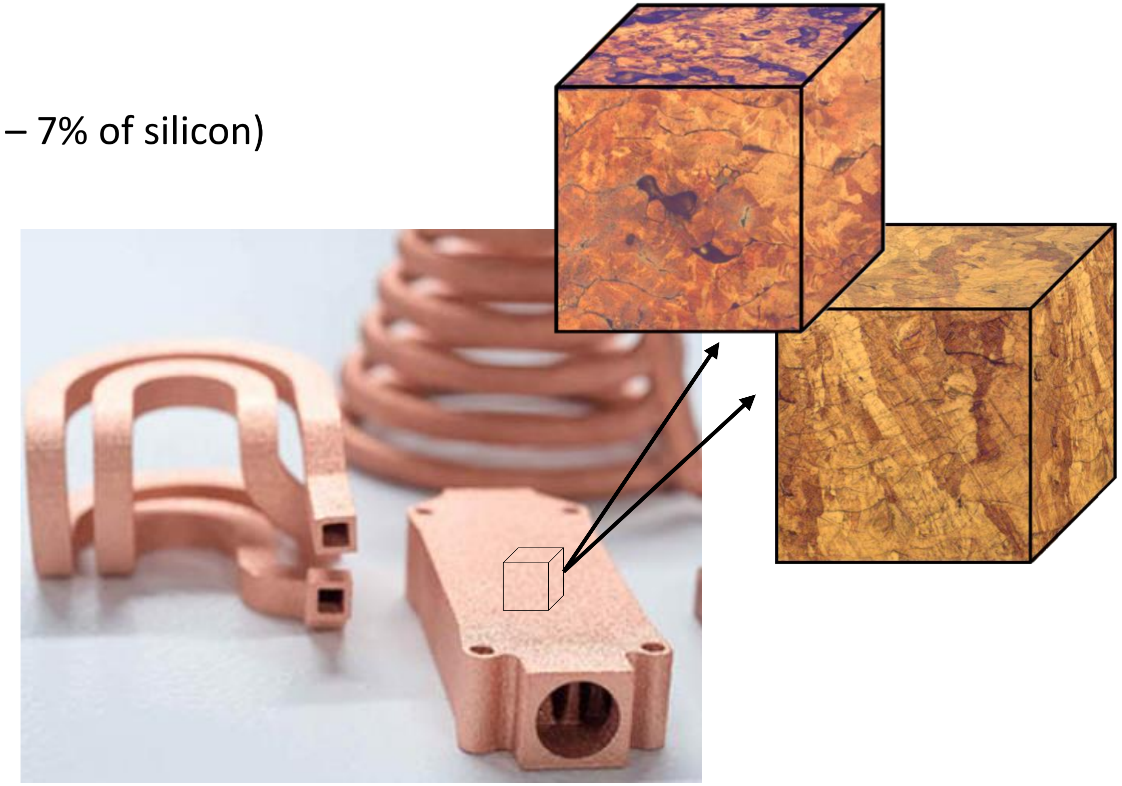
Design conceptualisation

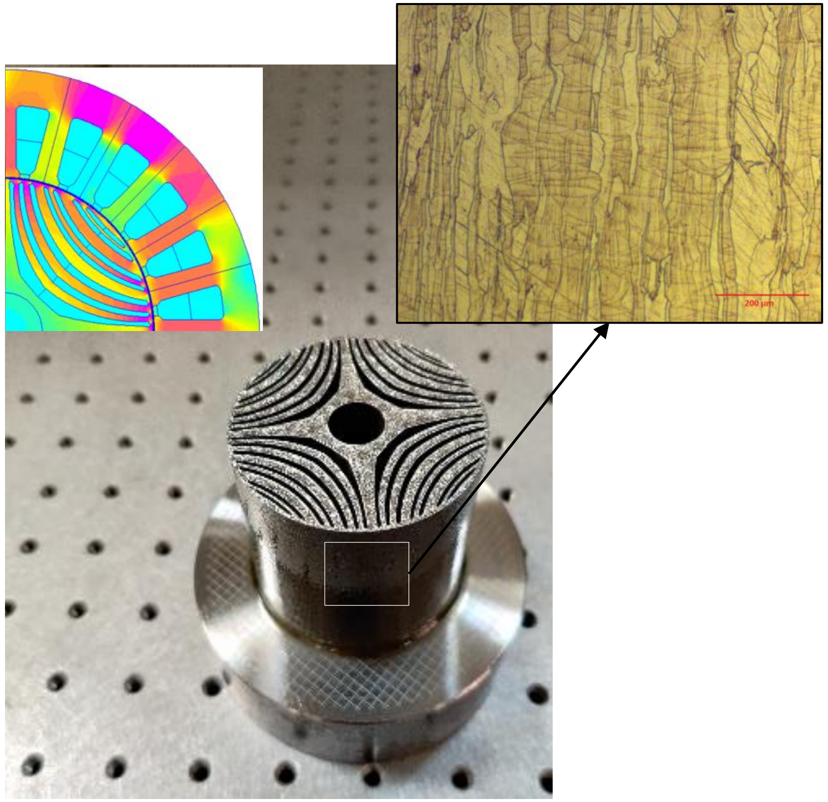
Prototype (application validation) *

Production lines (supplier identification)

Training

Copper alloys
Pure Iron
Ferrosilicon alloys (with 3 – 7% of silicon)
Alluminum alloys





* PORFESR ACMEC

# Industrial partners and collaborators

IPG PHOTONICS®

OPTOPRIM

PRECITEC

Ferrari

DUCATI

G.D
a coesia company

Tetra Pak®