The fundamental role of the nanoscale materials characterization in the automotive industry

CRF- Group Materials Labs

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Outline

I. Main drivers and targets for novel components

II. Where and Why materials integration: need a new approach in characterization

III. Three main examples of characterization improvements:

    I. Optical finishing
    II. Embedded electronics
    III. Multi-materials and miniaturization

IV. Conclusions

Mission

To develop and transfer innovative powertrains, vehicle systems & features, materials, processes and methodologies together with innovation expertise in order to improve the competitiveness of FCA products

To represent FCA in European and National collaborative research programs, joining pre-competitive projects and promoting networking actions

To support FCA in the protection and enhancement of intellectual property

Group Materials Labs: worldwide operations

900+
MATERIAL ANALYSIS EQUIPMENTS

350
QUALIFIED RESOURCES AS ENGINEERS, CHEMISTS, PHYSICIST AND MATHEMATICIANS

65
RESEARCH PROJECTS

50
YEARS EXPERIENCE

28
SUBJECT AREAS

16
RESEARCH LABORATORIES ALL OVER THE WORLD

5
TECHNICAL DEPARTMENTS

27
COMPETENCE CENTERS

Started on May 1st 2010

Headcount EU 193 I WW 350

Locations EU 9 I WW 16

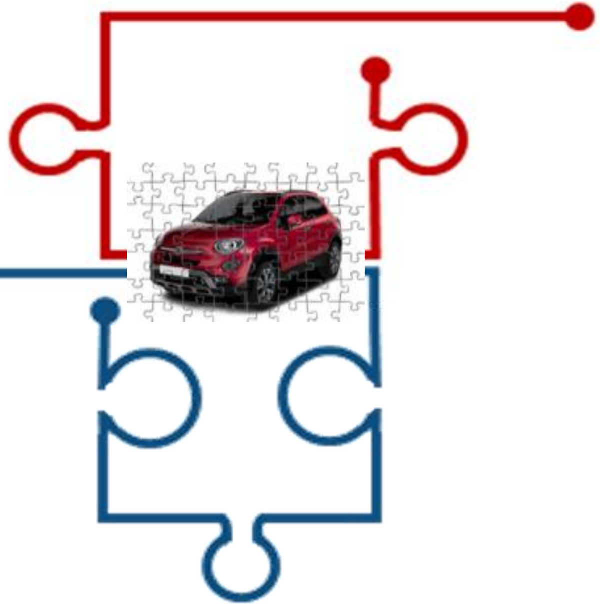
Assure up-to dated **competences**

Share best practices

Assure **equipment sharing and saturation**

Efficient labs activities

Needs, Targets, Priorities & Challenges



COUPLED
Activities on Products

Product Development:

- Materials engineering
- Materials Testing on components/vehicle
- Failure analysis

Product in production:

- Failure analysis
- Product materials compliance

DECOUPLED
Innovative Actions

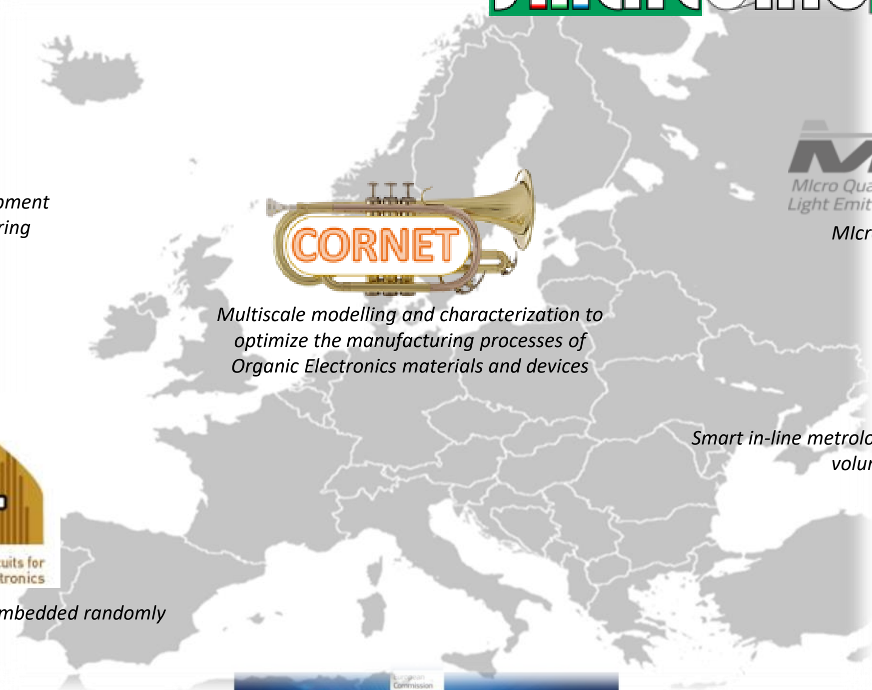
- Research
- Innovation
- Methodologies
- Materials application feasibility
- Materials characterization
- Materials environmental issues

Automotive Brands

DECOUPLED: National and International Collaborative Research projects examples

- H2020
- M-Eranet
- KIC RawMaterials

eit RawMaterials



Development of smart machines, tools and processes for the precision synthesis of nanomaterials with tailored properties for Organic Electronic

smartonics

MILEDI

MIcro Quantum Dot-Light Emitting Diode/Organic Light Emitting Diode - DIrect patterning

MIcro QD-LED/OLED DIrect micro patterning

Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing

appolo

CORNET

Multiscale modelling and characterization to optimize the manufacturing processes of Organic Electronics materials and devices

Smart line

Smart in-line metrology and control for boosting the yield and quality of high-volume manufacturing of Organic Electronics

TERA SEL

Thermoplastically deformable circuits for Embedded Randomly Shaped Electronics

Thermo-plastically deformable circuits for embedded randomly shaped electronics

HORIZON 2020

PULSE

High-Power Ultrafast LaSErs using Tapered Double-Clad Fibre

COUPLED: Brand Product Development

Automotive Brands

Concept	Definition	Execution	Industrialization	Market

New materials scouting

Assess application of new materials on PSP

Standards and specifications update taking also “lesson learned”.

Chemical and Physical analysis on materials

Metals & Polymers Testing

Tribology, Fatigue, Aging (Thermal & environmental), Surface

Metrology

- Components measurements;
- Instruments calibration

Validation and qualification

Assess feasibility on Style proposals

Anti-Corrosion

Environment

Paints aesthetical performance

Components assessment

Methodology survey and update

Failure analysis

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Needs, Targets, Priorities & Challenges

Every day our cars are being coming more like …

Movable living rooms:
- Entertainment
- Relaxing
- Autonomous Driving
- …

Movable batteries:
- Battery Electric Vehicle
- Tesla model S: 100kWh
- Nissan Leaf to Home
- …

Movable Computers:
- Autonomous driving
- ADAS
- Cameras
- RADAR
- LIDAR
- …

Movable smatphone:
- IoT
- Large area infotainment
- Entertainment devices
- Connectivity
- Touch
- …

Needs, Targets, Priorities & Challenges

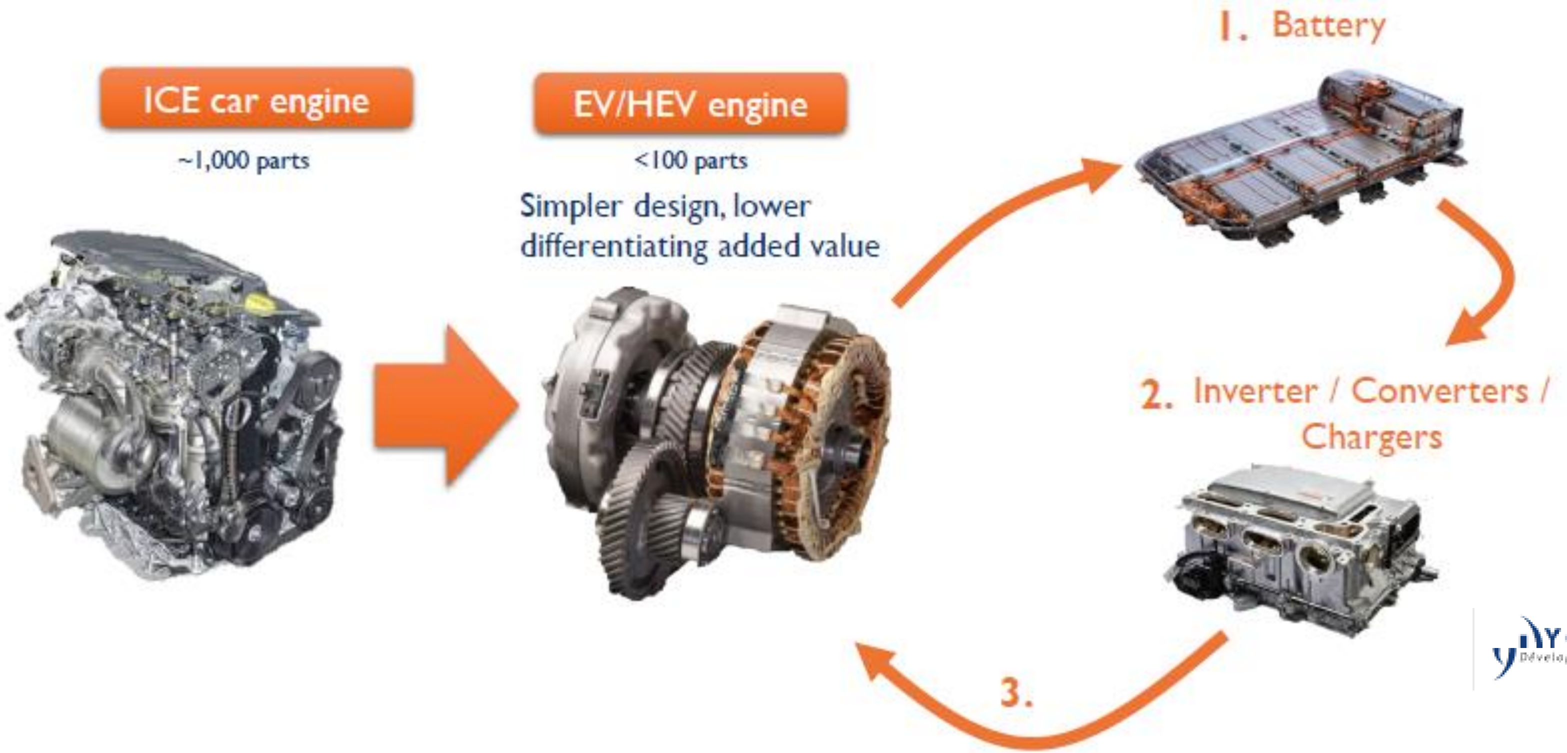
Interior & HMI

Chrysler Portal, EV of FCA @ CES 2018 Las Vegas

Mitsubishi concept 2017

Needs, Targets, Priorities & Challenges

EV/HEV



Needs, Targets, Priorities & Challenges

Materials:

- Bulk structural materials
- Coatings
- Resins

Functions (as electronics):

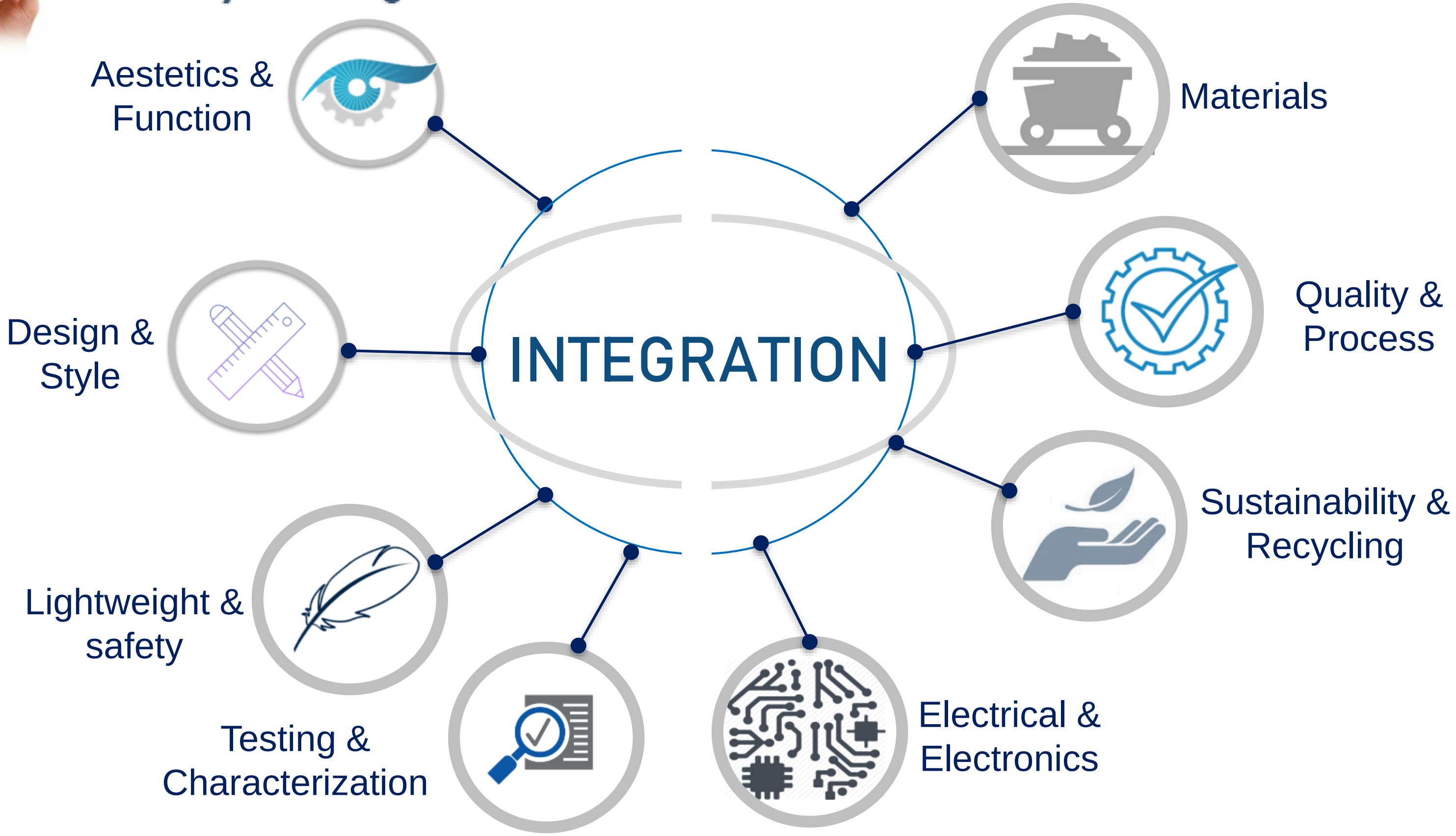
- Cabling
- Displaying
- Connectivity

Functional Active Materials:

- Embedded Organic Electronics
- Adaptive sensoring
- Data communication controls

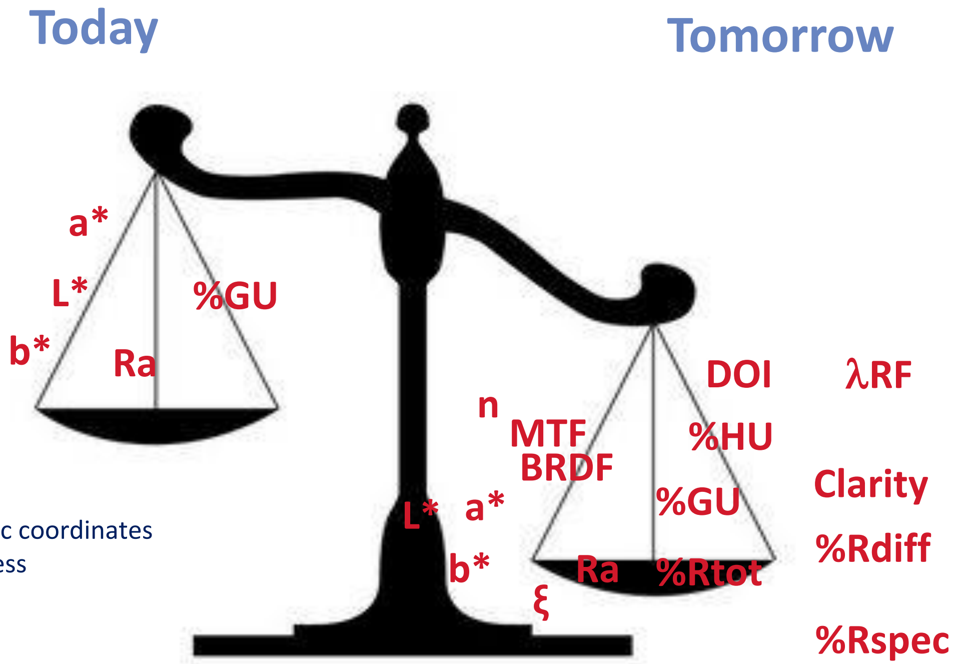
Needs, Targets, Priorities & Challenges

"The key challenge is non-technical. OEMs will need an overall culture shift."



Needs, Targets, Priorities & Challenges

New paradigm in characterization is needed (the case of Optical materials)



L*, a*, b* CIELAB chromatic coordinates
Ra Surface Roughness
GU Gloss

%Rtot Total reflectance
%Rdiff Diffuse reflectance
%Rspec Specular reflectance
DOI Distinctness of image
DAF Distribution of amplitude in profile
ξ Horizontal Correlation Length
Haze Turbidity or cloudiness
Clarity Clearness as to perception
BRDF Bidirectional Reflectance Distribution Function
λRF Birefringence
MTF Modulation Transfer Function
n refractive index

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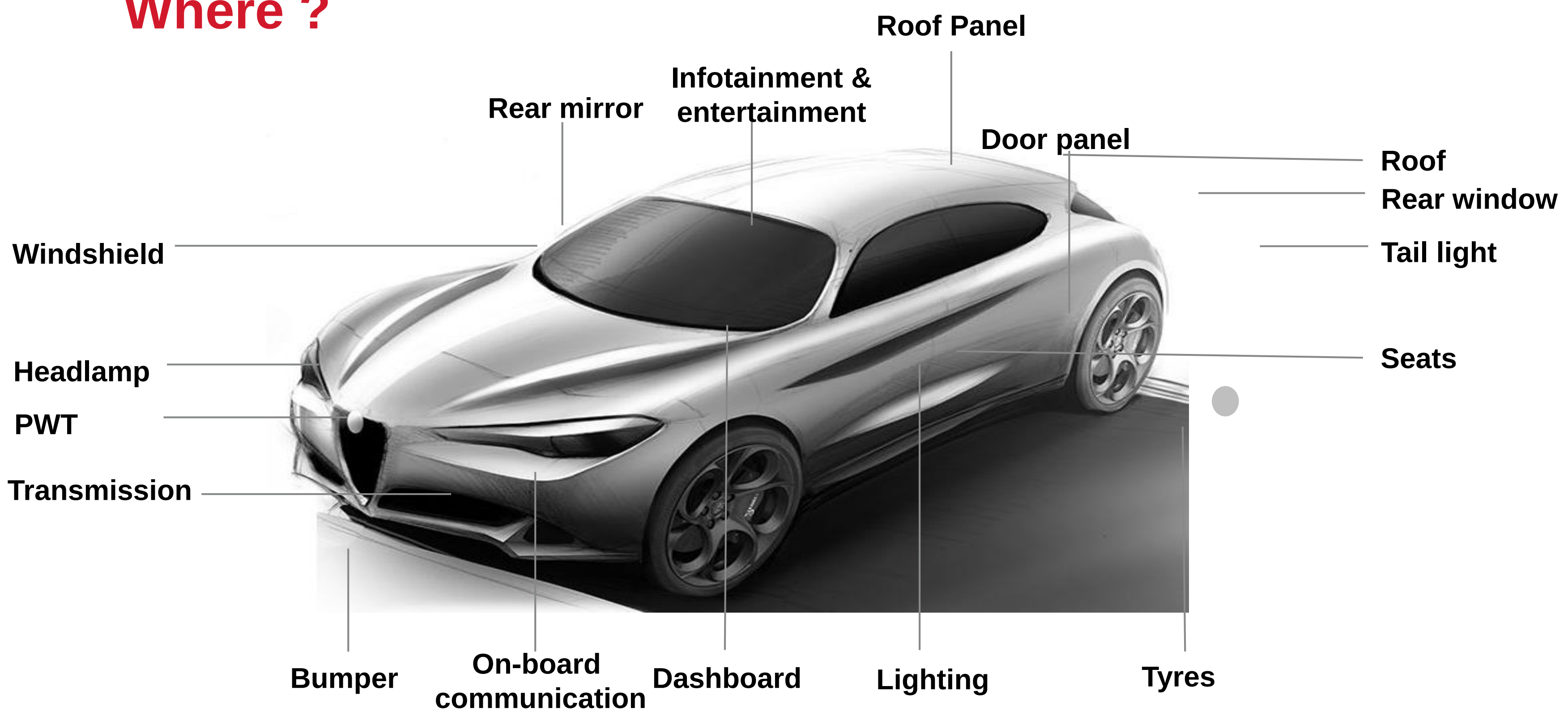
Needs, Targets, Priorities & Challenges

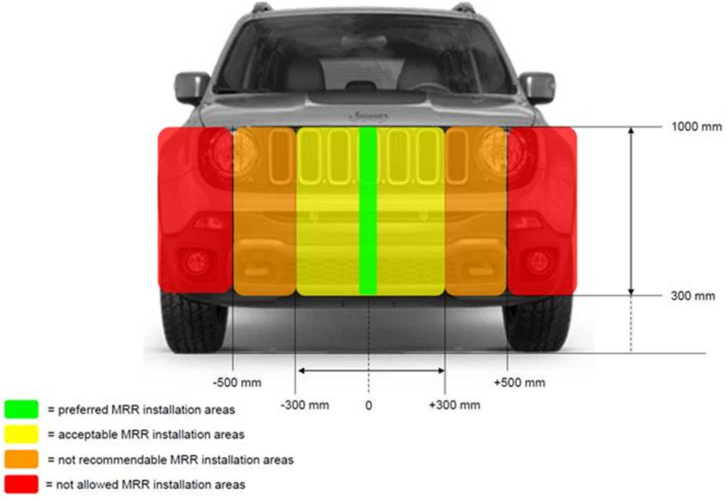
Where ?



Optical finishing

Description

- Displays exposed to sunlight are hard to read due to glare.
- Antennas and embedded communication
- Transparent materials for EM transmission
- Reflection issues to be managed on glass/plastic surface
- Fingerprinting issues



Effect

- Read-ability
- Clarity of the projected images
- Read-ability, visibility, blur, sparkling
- Mura effect

Development needs

New coatings development
- AntiGlare AG
- AntiReflective AR
- Antifingerprint AF

Conductive coating and plating
Definition of standard with EE Ergonomy

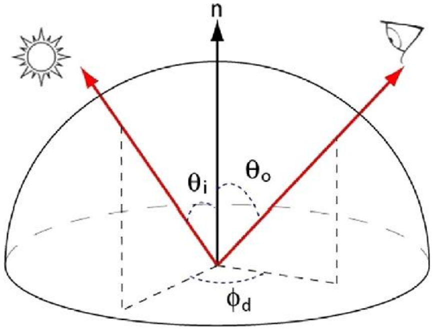
- Birefringence
- Clarity and sparkling

Materials: optical finishing

Optical finishing: AntiGlare and Clarity (Haze)

BRDF → R_t R_s R_d

BTDF → T_t H C



Where:
Bidirectional reflectance distribution function
Bidirectional Trasmittance distribution function
Rt is total reflection, **Rs** Specular Reflection, **Rd** Diffuse reflection
Tt Total Trasmittance, **H** Haze and **C** Clarity

Haze and Clarity

- **Haze:** $T^{90°}_{d,2.5°} = \frac{I^{90°}_{d,2.5°}}{I_i} \rightarrow H = \frac{T^{90°}_{d,2.5°}}{T_t}$
- **Clarity:** $T^{0.1°}_{d,0°} = \frac{I^{0.1°}_{d,0°}}{I_i} \rightarrow C = \frac{T^{0.1°}_{d,0°}}{T_t}$

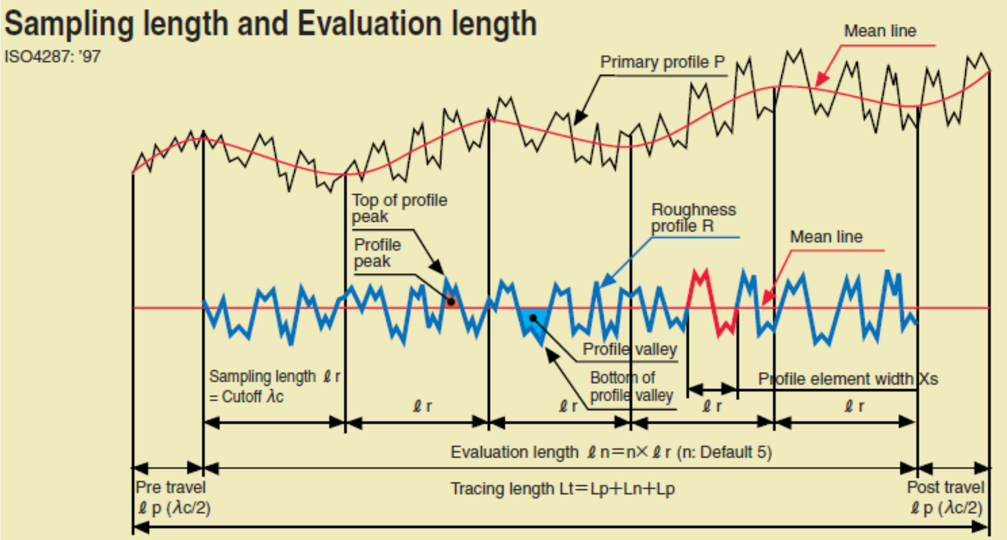
Optical finishing: sparkling

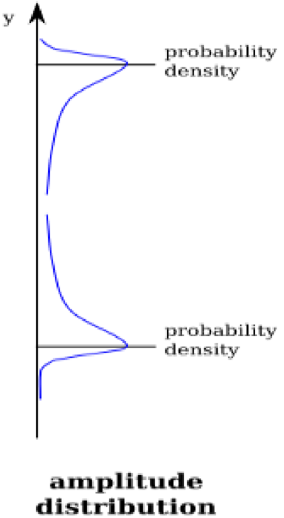
- **Same Ra** (Arithmetic mean of the absolute ordinate values Z(x) within a sampling length) for surfaces of widely different profiles
- **Horizontal Correlation Length (ξ) and Amplitude Density Function (ADF)** give information about the material and void volumes characterizing the surface topography

Average Roughness:

$$R_a = \frac{1}{l}\int_0^l |z(x)|dx$$

$$BRC(c) = \int_c^0 ADF(z)dz$$





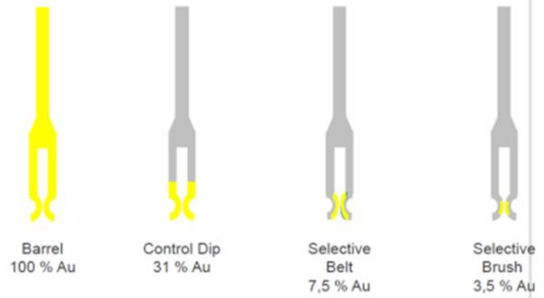
Embedded electronics

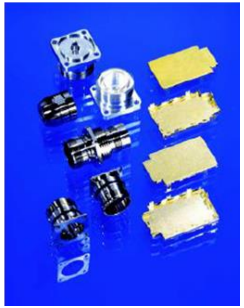
FIAT CHRYSLER AUTOMOBILES

Description

- Transparent conductive layer
- Organic and flexible electronics
- Multi-layered structures
- Joining and bonding materials
- Plating (selective)

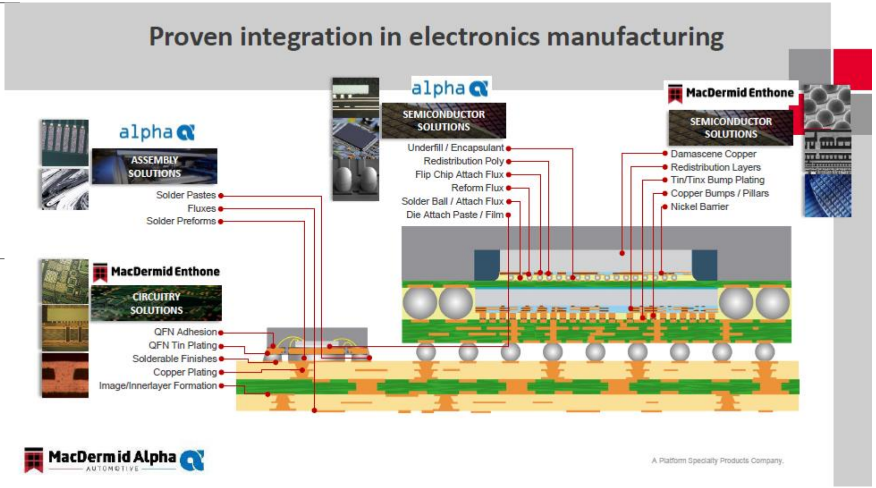
Multimetal plating on connecotrs





Effect

- EM noises
- Failure anticipation
- Feedback sensitivity
- Miniaturization
- Sintering and processing



Development Steps

- Procedure to measure thickness
- Interlayers
- Processes and low T sintering
- 3D joining

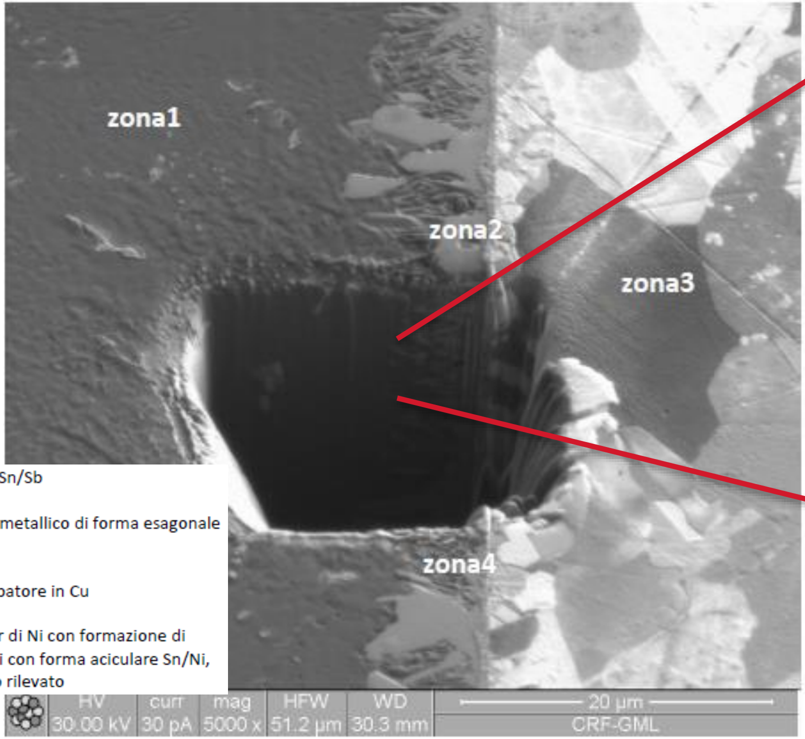
- Definition of new EE standards

Advanced electronic testing→ cross section analysis

Supporting for product development of advance cross section analysis

- Section by Focused Ion Beam Microscopy FIB

Soldering → Cu thermal dissipater on substrate Sn/Sb → Tin/Antimony

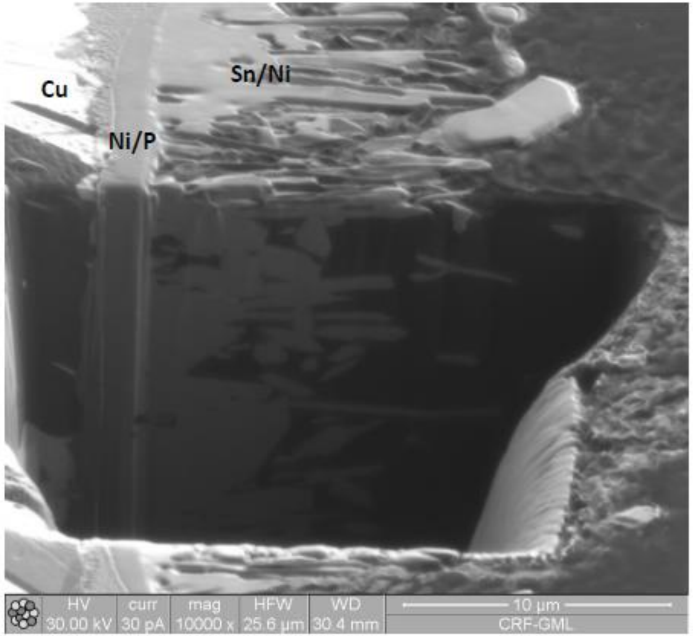


Zona 1: lega Sn/Sb

Zona 2: Intermetallico di forma esagonale Sn/Cu/Ni

Zona 3: dissipatore in Cu

Zona 4: Layer di Ni con formazione di intermetallici con forma aciculare Sn/Ni, P non è stato rilevato



- Intermetallic migration within substrate structure

Multi-materials/miniaturized components

Description

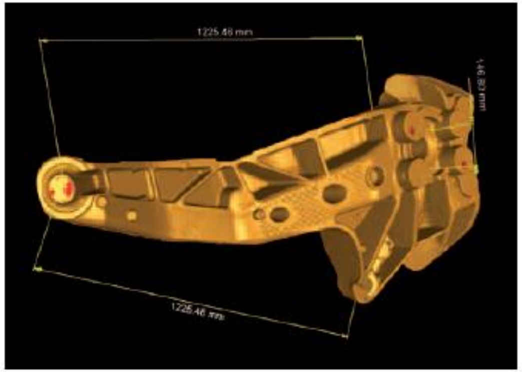
- Miniaturized connections
- Miniaturized sensors
- Multi-layered multi-materials
- Additive manufacturing powders
- Electrodes and electrolytes for batteries

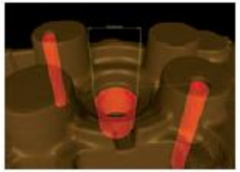
Effect

- Failures anticipation
- Custom components manufacturing
- Miniaturization

Development Steps

- Non-destructive testing
- Geometrical and metrological reconstructions
- Definition of new standards



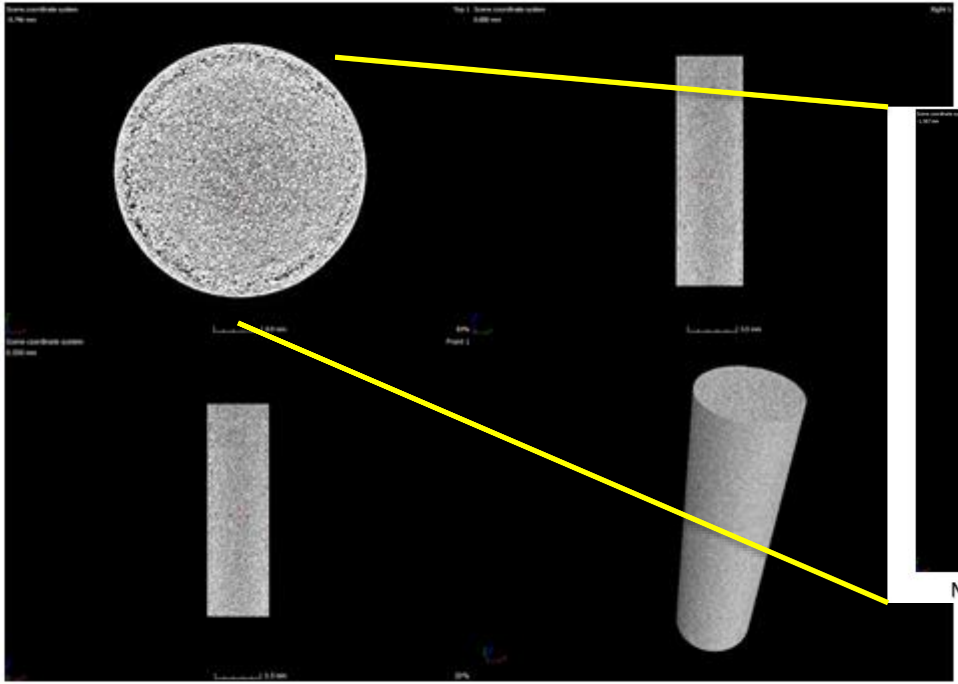


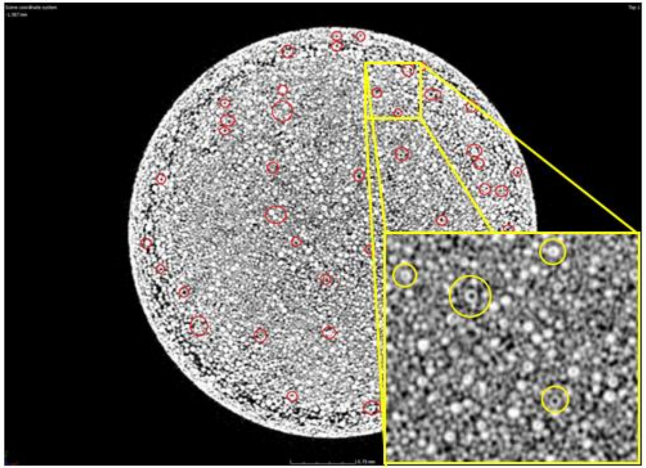
CTS Computer Tomography Scanning advanced analyis - Case AM

Case studies

Nell'Additive Manufacturing è fondamentale la **qualità delle polveri**

Esempio: analisi tomografica di un set di polveri con una **risoluzione a 10 µm**





Nell'esempio sono evidenziati in rosso granelli con porosità interne

Controllo Preventivo Polveri

Per gentile concessione del Sig. Leone Politecnico di Torino

Servizi di scansione con Tomografia Assiale Computerizzata (TAC)

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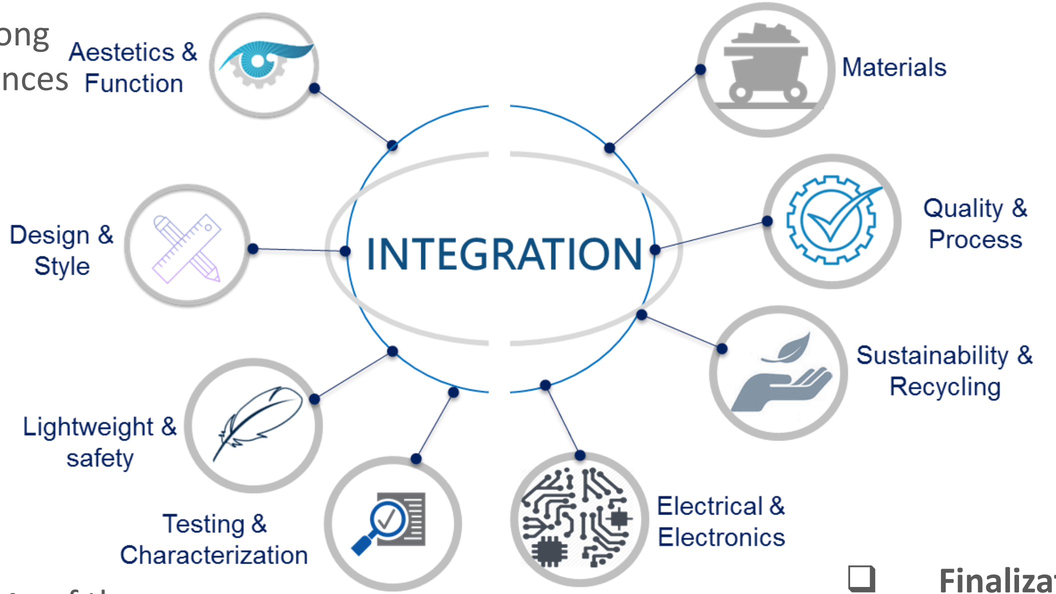
Conclusions & wrap-up

- **Integration** is possible by trade-off and collaborations among technical competences

- OEMs have to and need to **drive the suppliers**



- **Continuous update** of the materials' skill in testing

- **Finalization** of product/ technology/ materials to expected targets

Wrap-up

New paradigm in characterization is needed

Two steps of characterization:

Characterization clusters

1. Materials Analysis
2. Components Analysis

Characterization methodologies :

1. Chemical
2. Mechanical
3. Photo-electro physical
4. Interface and superficial
5. Environmental and aging

Wrap-up

MC: Major Challenges in methodologies

Red: CRF
Violet: LFoundry
Blu: Common

Main characterization analysis

Five characterization Methodologies

	Materials		Components
Chemicals & Elements	•XRD •EDS •Raman •ICP-MS •TERS	•EDS •FTIR •Raman •ICP-OES •XRD •UV-Vis •VPD-ICP-MS •Titration •EDS •SIMS •Raman •XRF •XRD •APT	•Corrosion •Humidity •Temperature
Mechanical	•Tensile stress •Traction •Ball test	•Tensile stress maping	•Tensile stress •Traction •Ball test
Photo- Electro Physical	•Ultrasonics •IR •Penetrating liquid •Endoscopic •Radiography •CTS •IR emissivity •Neutron •Electrical Failure Analysis •Dark current spectroscopy	•IR emissivity •XRD •SRP •Mercury probe •DLTS •Parametric Analyzer	
Physics & superficial	•Tensile stress •Ultrasounds •IR •Endoscopic •Eddy current	•Contact profilometry •Optical profilometry •Micrography (SEM-FIB-TEM) •XPS • AFM	
Environment & aging		•Wear •Abrasion	•UV exposure •Humidity •Temperature •Operative endurance

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Thank you

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