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

CRF- Group Materials Labs

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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 | WW 350
Locations: EU 9 | WW 16

Assure up-to dated competences
Share best practices
Assure equipment sharing and saturation
Efficient labs activities
Needs, Targets, Priorities & Challenges

DECOUPLED
Innovative Actions

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

COUPLED
Activities on Products

Product Development:
- Materials engineering
- Materials Testing on components/vehicle
- Failure analysis

Product in production:
- Failure analysis
- Product materials compliance

Automotive Brands
DECOUPLED: National and International Collaborative Research projects examples

- H2020
- M-Eranet
- KIC RawMaterials

**Hub of Application Laboratories for Equipment Assessment in Laser Based Manufacturing**

**smartonics**

**CORNET**

**TERASEL**

**PULSE**

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

**Thermo-plastically deformable circuits for embedded randomly shaped electronics**

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

**Micro QD-LED/OLED Direct micro patterning**

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

**High-Power Ultrafast Lasers using Tapered Double-Clad Fibre**
COUPLED: Brand Product Development

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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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

1. Battery
2. Inverter / Converters / Chargers
3.
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
“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?

- Roof
- Rear window
- Tail light
- Seats
- Door panel
- Roof Panel
- Infotainment & entertainment
- Rear mirror
- Door panel
- Windshield
- Headlamp
- PWT
- Transmission
- Bumper
- On-board communication
- Dashboard
- Lighting
- Tyres
- PWT
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
Materials: optical finishing
Optical finishing: AntiGlare and Clarity (Haze)

Where:
Bidirectional reflectance distribution function
Bidirectional Transmittance distribution function
$R_t$ is total reflection, $R_s$ Specular Reflection, $R_d$ Diffuse reflection
$T_t$ Total Transmittance, $H$ Haze and $C$ Clarity

Haze and Clarity

- Haze: $T_{d,2.5^\circ}^{90^\circ} = \frac{I_{d,2.5^\circ}^{90^\circ}}{I_i} \Rightarrow H = \frac{T_{d,2.5^\circ}^{90^\circ}}{T_t}$

- Clarity: $T_{d,0^\circ}^{0.1^\circ} = \frac{I_{d,0^\circ}^{0.1^\circ}}{I_i} \Rightarrow C = \frac{T_{d,0^\circ}^{0.1^\circ}}{T_t}$
• **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

**Optical finishing: sparkling**

**Average Roughness:**

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

**BRC(c):**

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

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**Sampling length and Evaluation length**

- Sampling length \( r = \text{Cut-off } \lambda_c \)
- Evaluation length \( n = n \lambda r \)
- Probability density
- Amplitude distribution
Embedded electronics

Description

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

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

Multimetal plating on connectors

Proven integration in electronics manufacturing
Advanced electronic testing $\rightarrow$ cross section analysis

Supporting for product development of advance cross section analysis
- Section by Focused Ion Beam Microscopy FIB

Soldering $\rightarrow$ Cu thermal dissipater on substrate Sn/Sb $\rightarrow$ Tin/Antimony

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

Continuous update of the materials’ skill in testing

- Integration
- Finalization
- OEMs have to and need to drive the suppliers
- Conclusions

INTEGRATION

- Aesthetics & Function
- Design & Style
- Lightweight & safety
- Testing & Characterization
- Electrical & Electronics
- Materials
- Quality & Process
- Sustainability & Recycling
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

Main characterization analysis

Materials
- XRD
- EDS
- Raman
- ICP-MS
- TERS

Components
- EDG
- FTIR
- ICP-OES
- UV-Vis
- VP-OICP-MS-Titration
- SIMS
- Raman
- XRF

Chemicals & Elements
- Corrosion
- Humidity
- Temperature

Mechanical
- Tensile stress
- Traction
- Ball test

Photo-Electro Physical
- Ultrasonics
- IR
- Penetrating liquid
- Endoscopic
- Radiography
- CTS
- IR emissivity
- Neutron
- Electrical Failure Analysis
- Dark current

Technologies
- IR emissivity
- XRD
- SRP
- Mercury probe
- Parametric Analyzer
- DLTS

Physics & Superficial
- Tensile stress
- Ultrasound
- IR
- Endoscopic
- Eddy current

Environment & Aging
- Wear
- Abrasion
- UV exposure
- Humidity
- Temperature
- Operative endurance
Thank you
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