UNITA' OPERATIVA DI RICERCA 4 – INGEGNERIZZAZIONE DI RIVESTIMENTI ALLA MACRO-MICRO SCALA

RESPONSABILE: Prof. Tiziano Manfredini

INGEGNERIZZAZIONE DI RIVESTIMENTI ALLA MACRO-MICRO SCALA

progettazione, realizzazione e applicazioni di **rivestimenti** e **trattamenti superficiali** per la **protezione** e **funzionalizzazione** di componenti meccanici

RESPONSABILE: **Prof. Tiziano Manfredini**

metodi di deposizione ad **alta temperatura** (**diffusione** via pack, **termospruzzatura**)	tecniche **elettrochimiche**	trattamenti superficiali con **film polimerici**

PERSONALE DIMA COINVOLTO:

Prof. Massimo Messori (Professore Associato)
Prof. Valeria Cannillo (Professore Associato)
Dott. Luca Lusvarghi (Ricercatore)
Dott. Roberto Giovanardi (Ricercatore)
Dott. Paola Miselli (Tecnico)
Dott. Giulia Scatasta (Tecnico amministrativo)

ASSEGNISTI DI RICERCA:

Dott. Ing. Giovanni Bolelli: “Sviluppo di rivestimenti e trattamenti di superficie innovativi per la meccanica avanzata e settori affini”
Dott. Ing. Benedetta Bonferroni: “Studio sperimentale di trattamenti diffusivi e di metodi per la protezione contro la corrosione e l’ossidazione ad alta temperatura”
Dott. Micaela Degli Esposti: “Progettazione e sintesi di nuovi materiali funzionali per il settore biomedicale e alimentare”

INGEGNERIZZAZIONE DI RIVESTIMENTI ALLA MACRO-MICRO SCALA

progettazione, realizzazione e applicazioni di **rivestimenti** e **trattamenti superficiali** per la **protezione** e **funzionalizzazione** di componenti meccanici

metodi di deposizione ad **alta temperatura** (**diffusione** via pack, **termospruzzatura**)

- processi di **diffusione in atmosfera controllata e in vuoto**: protezione da usura, ossidazione e corrosione a caldo di leghe e rivestimenti a base Fe, Ni e Co
- rivestimenti **termospruzzati cermets o leghe metalliche a base Fe**: protezione da usura e corrosione, minor costo, basso impatto ambientale

tecniche **elettrochimiche**

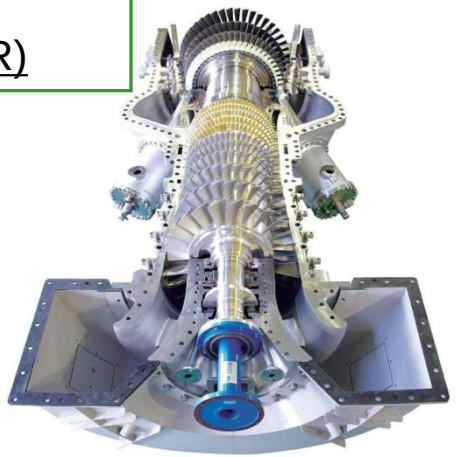
- metodi innovativi di **elettrodeposizione** di **rivestimenti metallici**: incremento della resistenza a usura e corrosione
- ottimizzazione della **composizione chimica** dei bagni per depositare Cr da Cr(III)
- ottimizzazione dei **parametri elettrici** di deposizione per depositare Cr da Cr(III)

trattamenti superficiali con **film polimerici**

- progettazione e sintesi di **sensori ottici** per misura on-line di diverse proprietà
- progettazione e sintesi di **imballaggi attivi** per usi alimentari

DIFFUSION COATINGS FOR PROTECTION OF GAS TURBINE BLADES

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED COMPANY: Turbocoating S.p.A., Rubbiano di Solignano (PR)

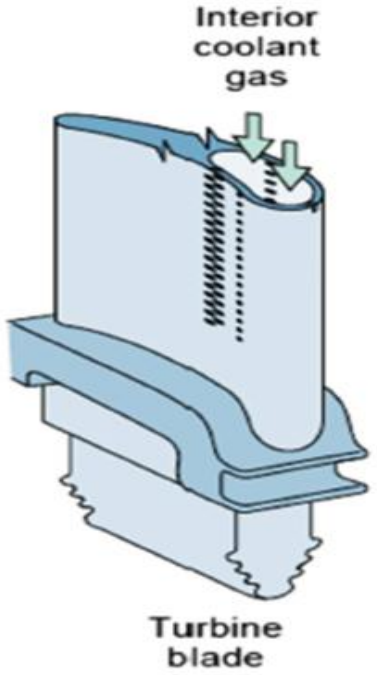


GAS TURBINES for power generation
BOILERS, HEAT EXCHANGERS, WASTE INCINERATORS

exposion to high temperatures (T>1000° C), corrosive athmospheres

Material: **Nickel superalloys** (es. Inconel 738)
Steel (C steel, ferritic steel, etc.)

Pack / above-the-pack cementation process, chemical vapour deposition (CVD): suitable coating techniques for complex shapes and internal diameters

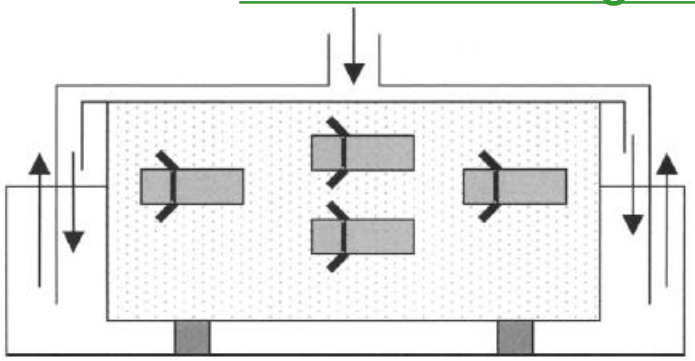


Alloy surface layer (10-100μm) enriched with **oxide scale formers**: intermetallics
- Oxidation protection: **Al**
- Hot corrosion protection: **Al + Cr, Si**

Controlled growth of **oxide scale**: **protection** of the component

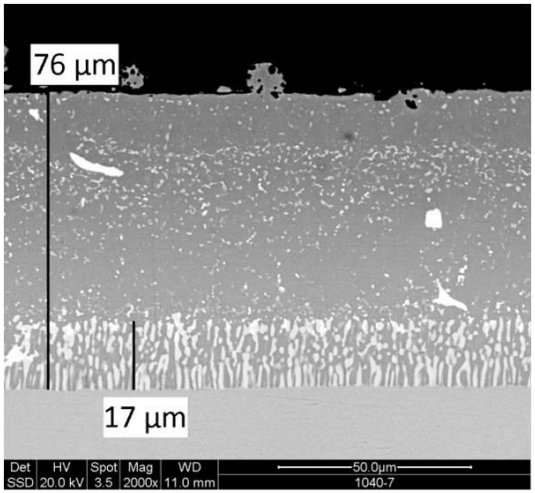
DIFFUSION COATINGS

Pack aluminizing of Inconel 738 @ Turbocoating S.p.A.



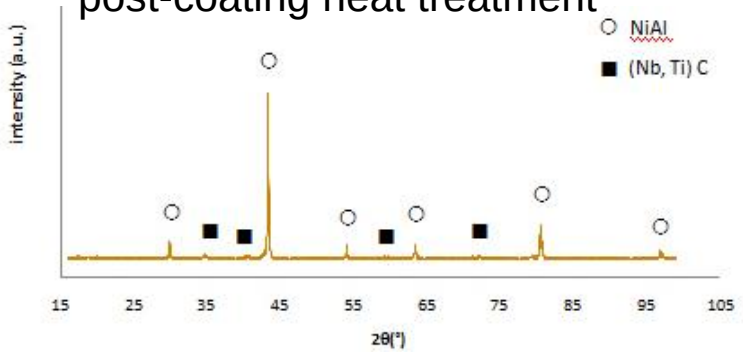
- Samples buried in the **pack mix powder**: source of Al (M-Al), activator, inert (alumina)
- Retort heated in a **protective atmosphere (Ar) furnace**
- Post-coating heat treatment in **vacuum**

Characterization of aluminized samples @ DIMA-UNIMORE



X-ray Diffraction

- β-NiAl phase formation after post-coating heat treatment



The requirements of turbines OEMs are satisfied

Scanning Electron Microscopy (SEM) + Energy-Dispersive X-ray spectroscopy (EDX)

- Surface layer of Ni-Al intermetallics
- Thikness: 20-100µm
- Interdiffusion zone: precipitation of alloy elements carbides (W, Ti, Ta)

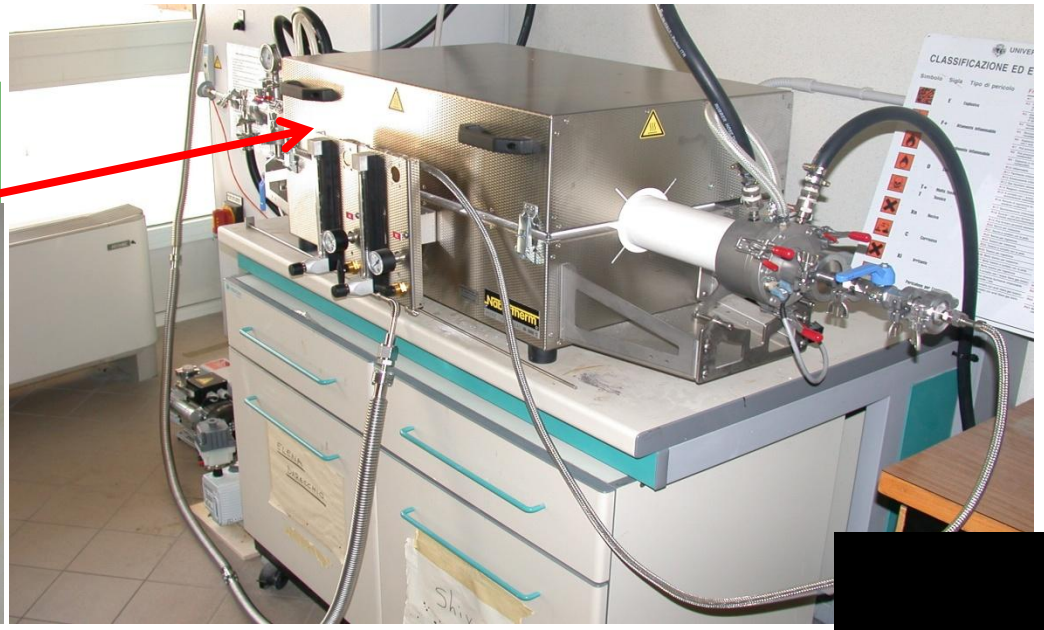
DIFFUSION COATINGS

Production of experimental coatings @ DIMA-UNIMORE

Treatment in **controlled atmosphere / vacuum furnace**

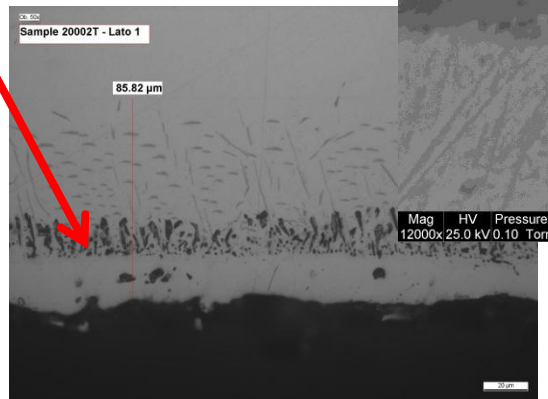
Optimization of the **pack mix formulation**

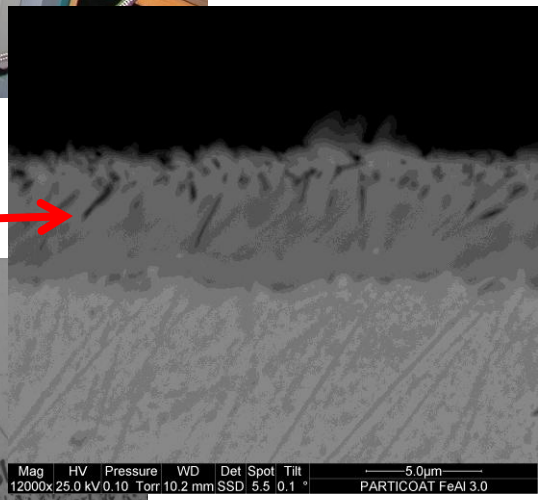




Ongoing DIMA-Turbocoating joint reserarches

- Aluminizing
- Chromizing
- Al-Cr, Al-Si diffusion coatings

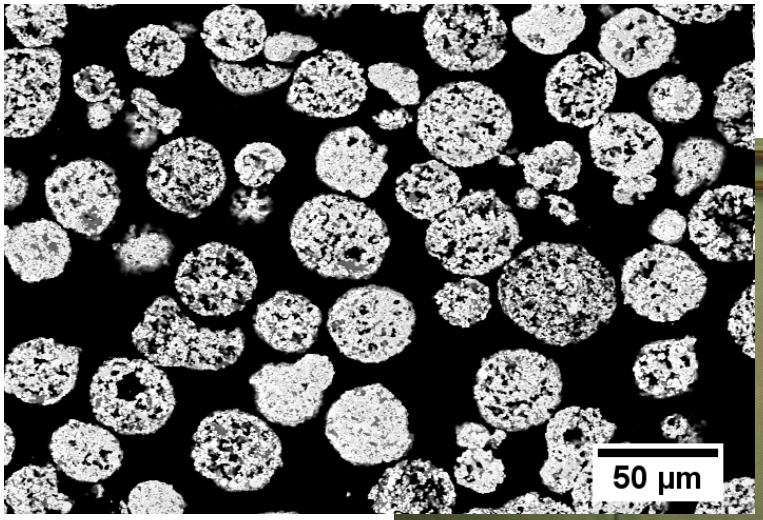




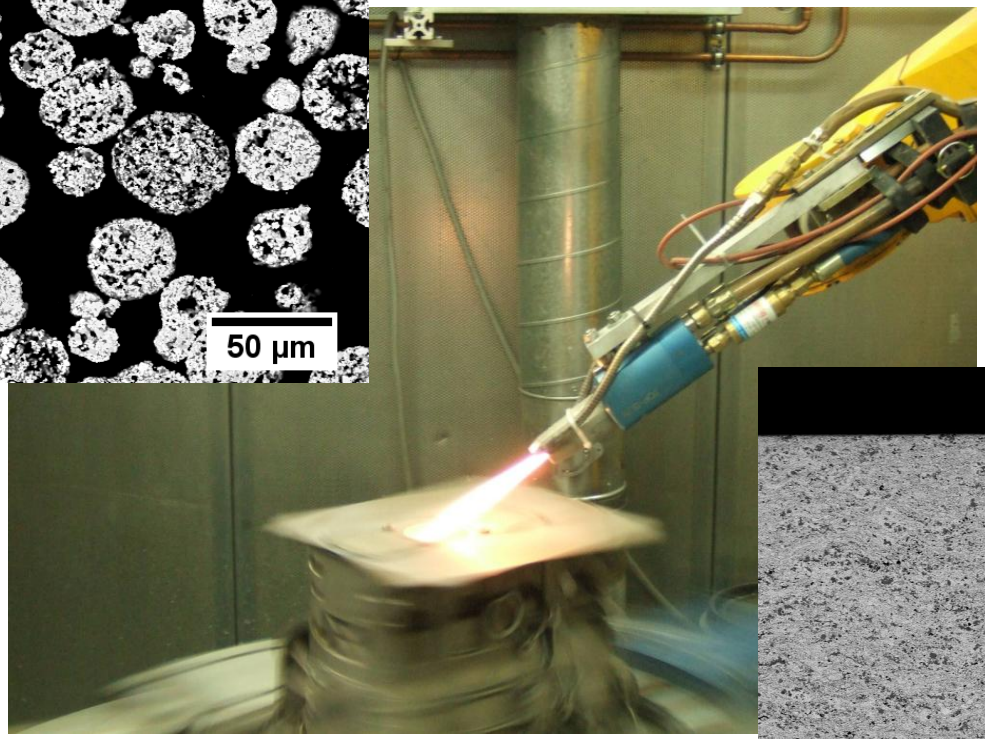
- OEMs requirements check: thickness, chemical composition, phase structure

THERMAL SPRAY COATINGS

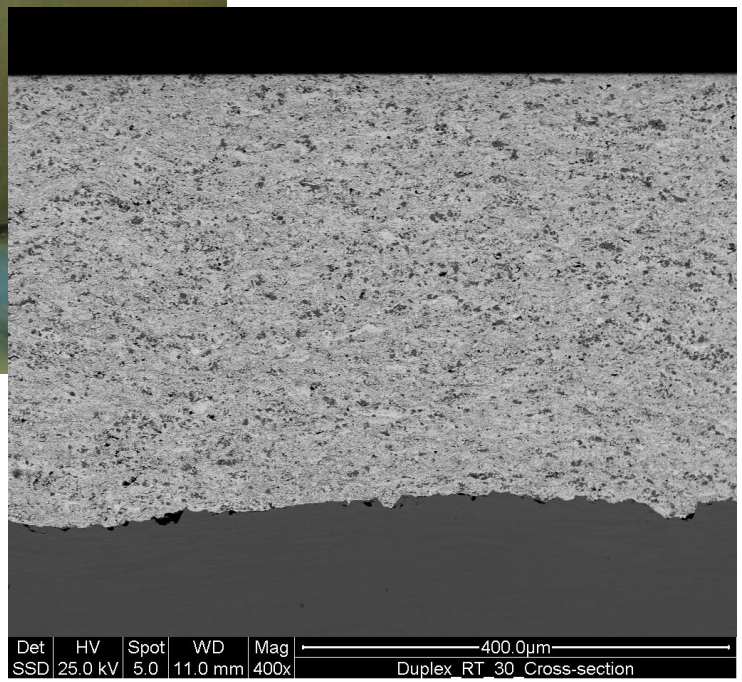
POWDER



SPRAY PROCESS



COATING

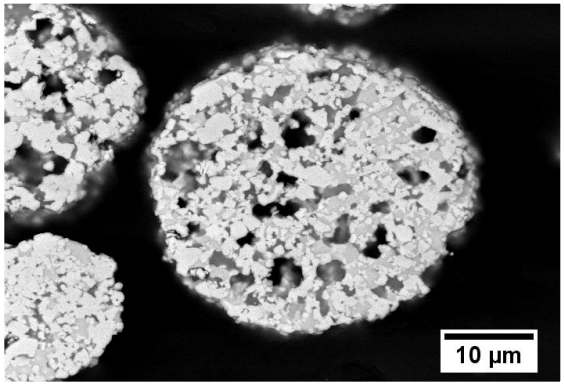
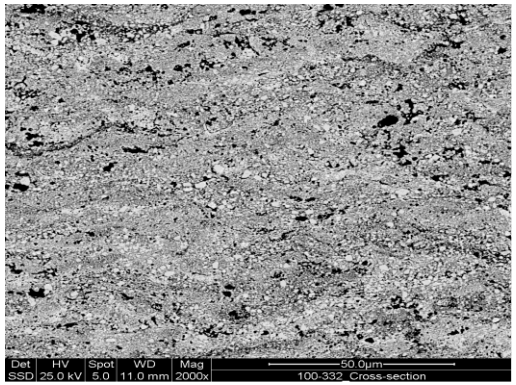
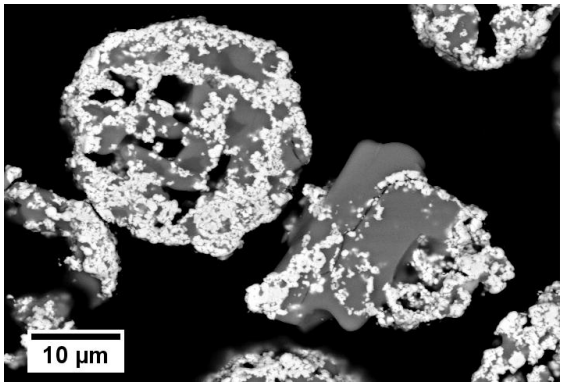
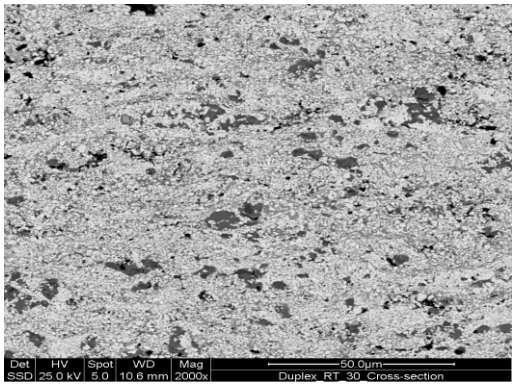


THERMAL SPRAY COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: Fraunhofer Institute IWS, Dresden (D)

METAL + CERAMIC (CERMET) COATINGS FOR WEAR PROTECTION

Resistance to severe sliding, abrasive or erosive wear
Operating temperature: R.T. to ≈750 ° C

MATERIAL	POWDER	COATING
WC-10%Co-4%Cr		
WC-20%$(W,Cr)_2C$-7%Ni		

THERMAL SPRAY COATINGS

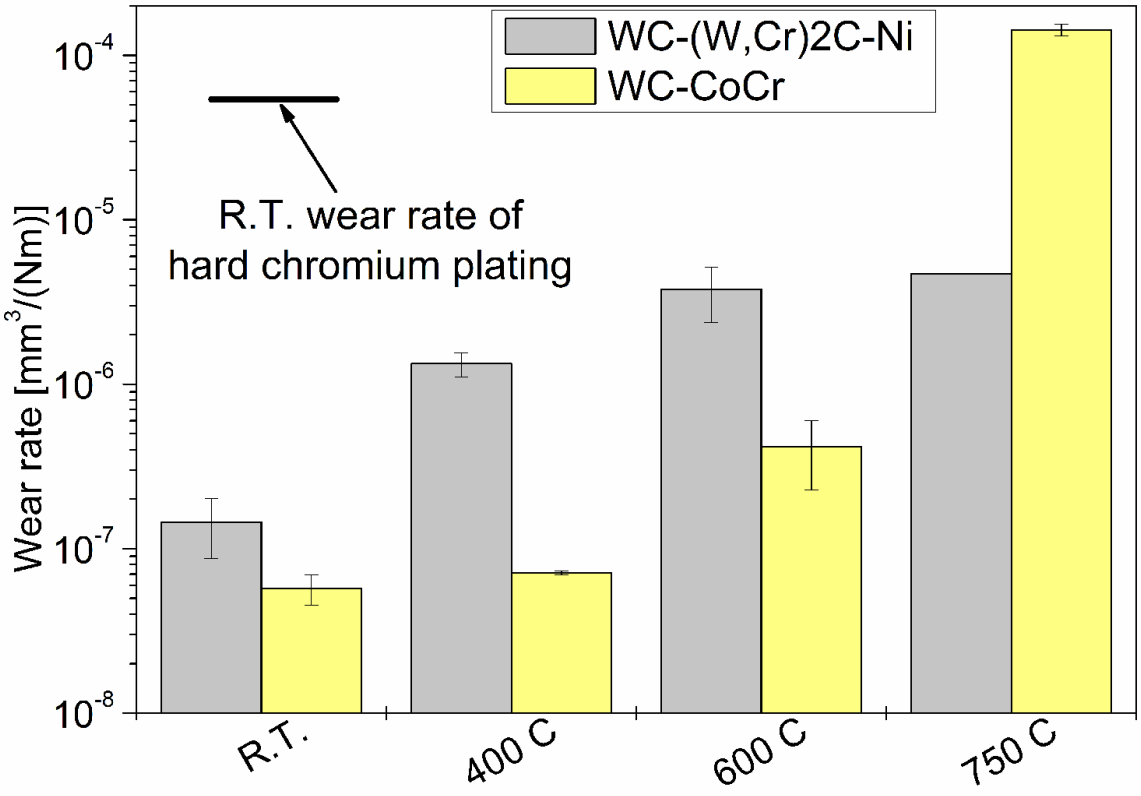
RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: Fraunhofer Institute IWS, Dresden (D)

METAL + CERAMIC (CERMET) COATINGS FOR WEAR PROTECTION

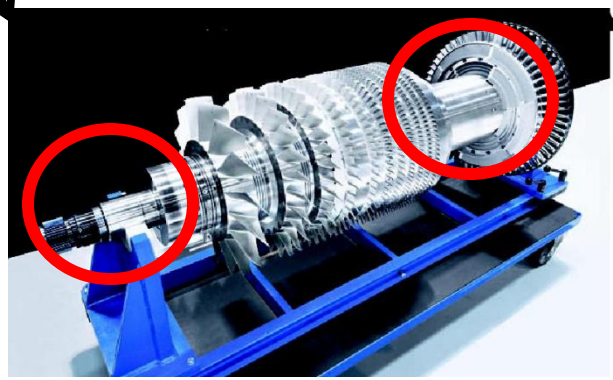
WC-CoCr
WC-$(W,Cr)_2C$-Ni

Best wear resistance at R.T.
Resistant up to 750 ° C

BOTH ARE SUPERIOR TO HARD CHROMIUM







THERMAL SPRAY COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: VTT Technical Research Centre, Espoo (FIN)

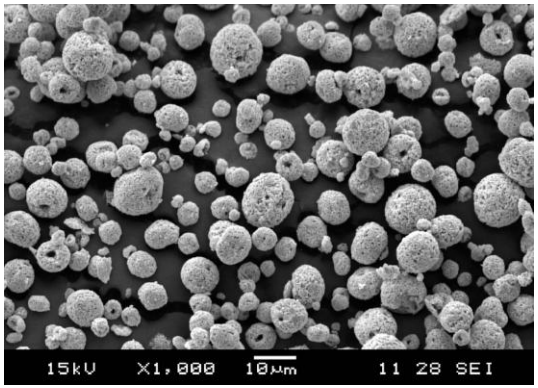
METAL + CERAMIC (CERMET) COATINGS FOR WEAR PROTECTION

Resistance to severe sliding, abrasive or erosive wear
Experimental coatings containing nanometric WC particles
Increase of hardness and fracture toughness

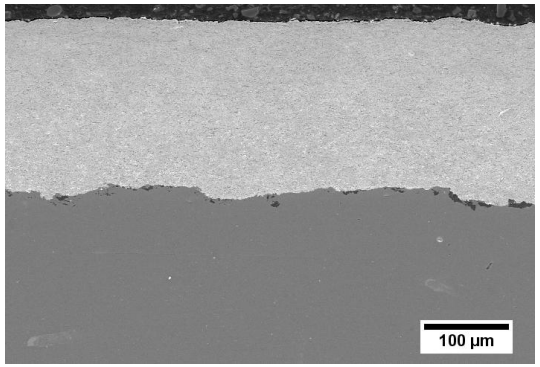
MATERIAL

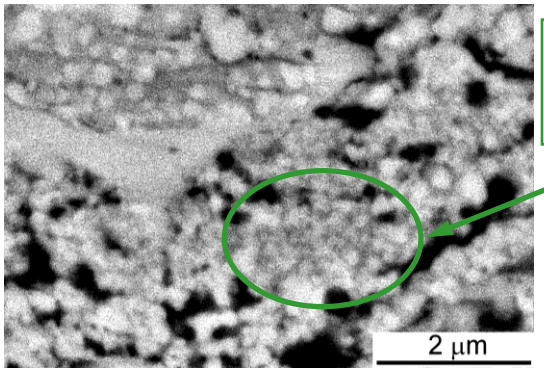
WC-10%Co-4%Cr
(0.2 µm WC)

POWDER



COATING



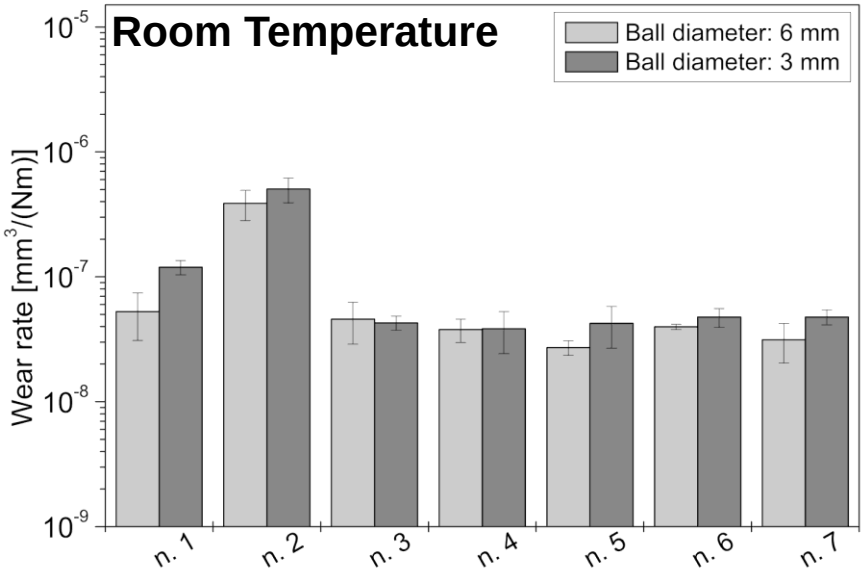


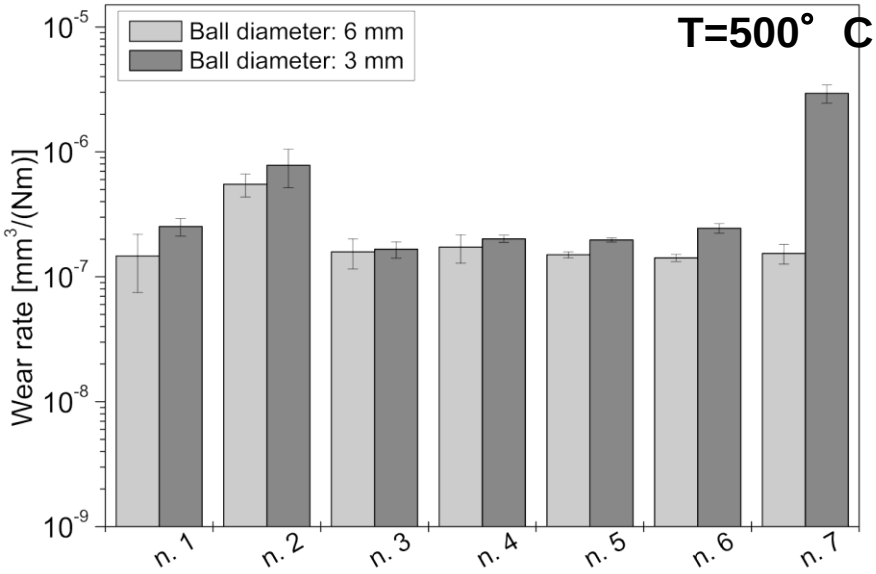
Fine carbide particles

THERMAL SPRAY COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: VTT Technical Research Centre, Espoo (FIN)

METAL + CERAMIC (CERMET) COATINGS FOR WEAR PROTECTION





n.1
n.2
n.3
n.4
} Coatings from experimental nanostructured powders

n.5
n.6
n.7
} Coatings from WC-10wt%Co-4wt%Cr commercial powders

wear resistance comparable to traditional cermet coatings

THERMAL SPRAY COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: Surface Engineering Lab., Tampere University of Technology (FIN)

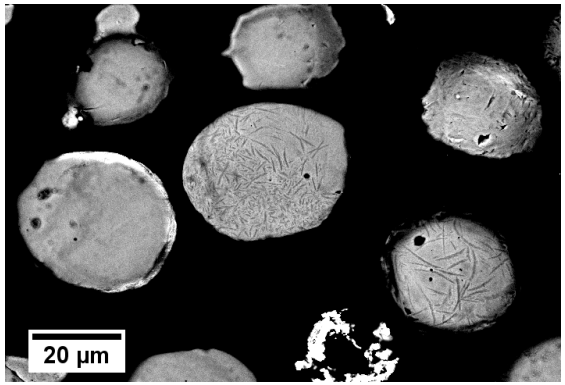
Fe-BASED METAL ALLOY COATINGS FOR WEAR AND CORROSION PROTECTION

Wear resistant up to 700° C (at least)
Non-toxic, anallergic – ideally suited for the food and packaging industry
Alternative to hard chromium plating and to Ni-based coatings

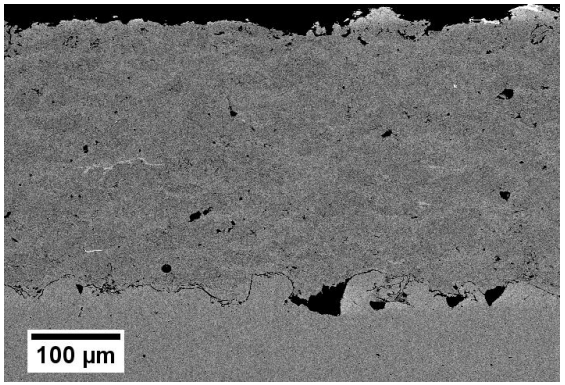
MATERIAL

COLFEROLOY:
Fe-31%Cr-(8-12)%Ni-3.6%B-0.6%C

POWDER



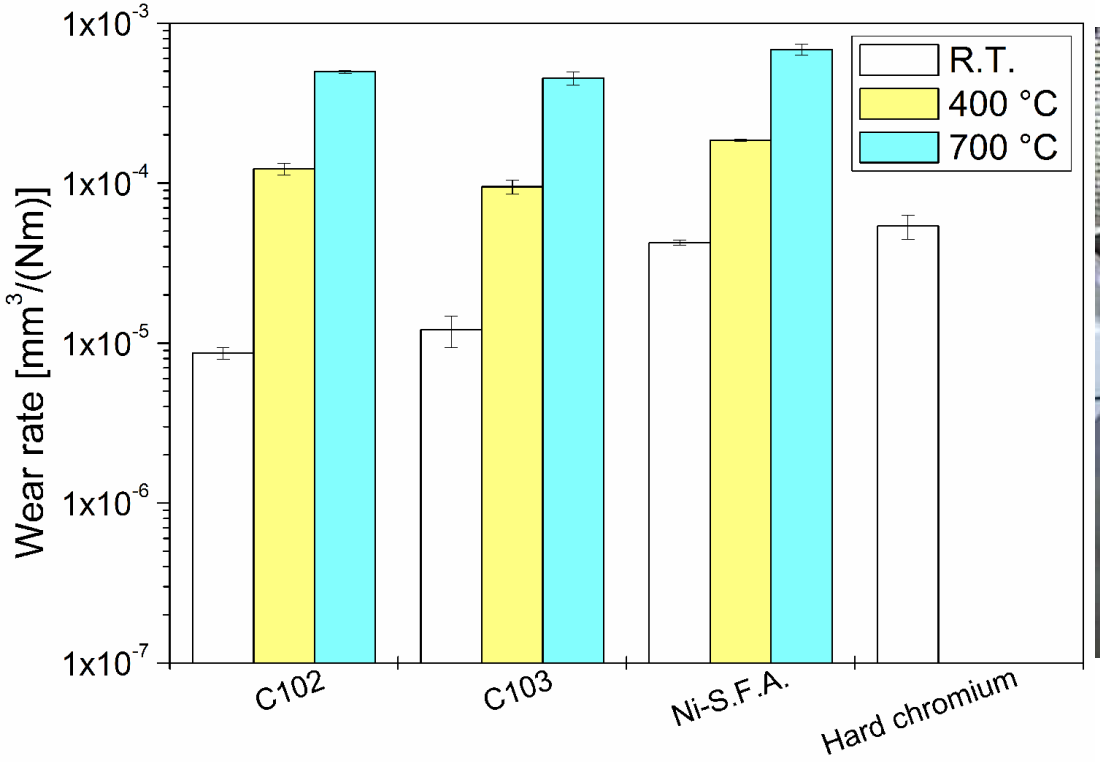
COATING



THERMAL SPRAY COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE
INVOLVED RESEARCH CENTRE: Surface Engineering Lab, Tampere University of Technology (FIN)

Fe-BASED METAL ALLOY COATINGS FOR WEAR AND CORROSION PROTECTION





Wear resistant up to 700° C (at least)
Better wear resistance than electrolytic hard chromium and Ni-based alloy
Does not release Ni and NiO in the wear debris
Ideally suited for food packaging and processing applications

ELOCTRODEPOSITED COATINGS

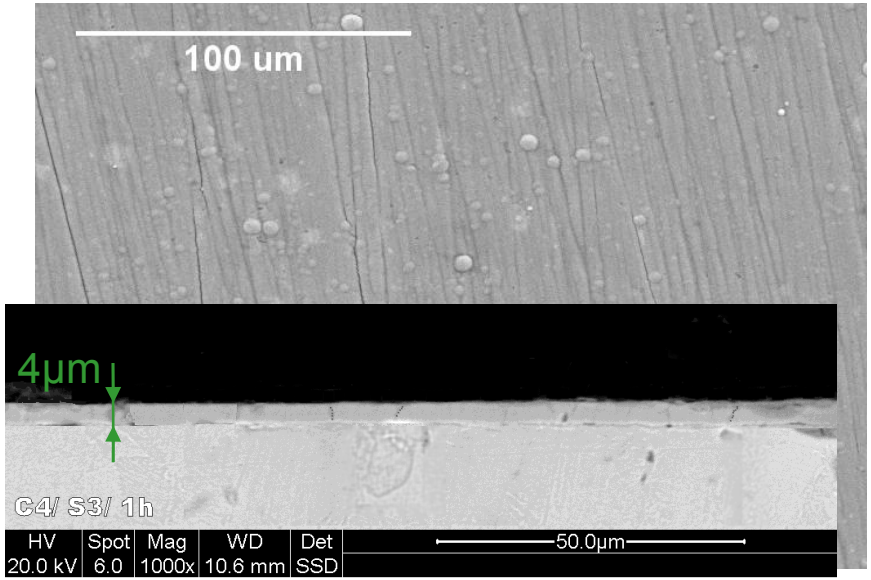
RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE

CHROMIUM ELECTRODEPOSITION FROM Cr(III) SOLUTION

Alternative to hard chromium plating from Cr(VI) solutions
Deposition from Cr(III) solution is achieved using a specific ligand for the Cr^{3+} ion: ***formic acid***
The best results obtained after optimization of the chemical composition of deposition bath are:

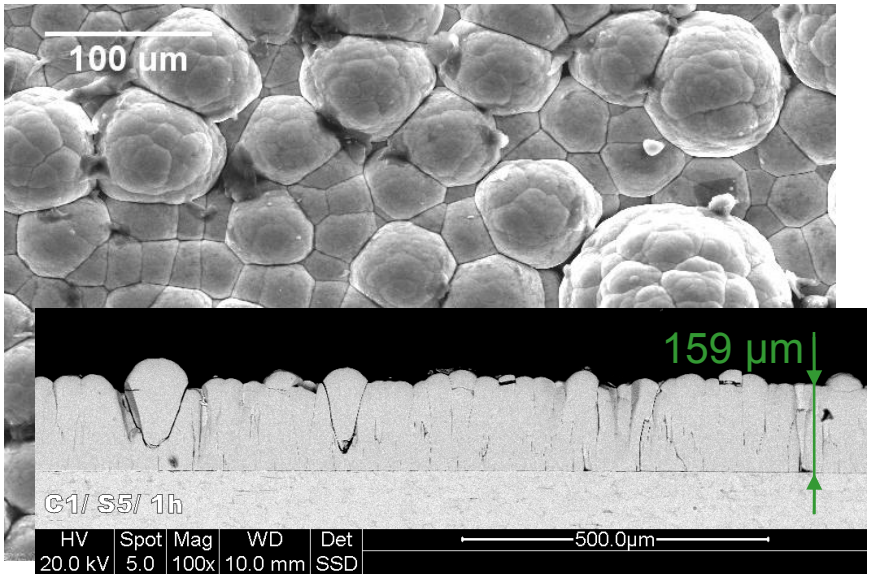
Solution 1

- good **adhesion**
- low surface **roughness**
- excellent **finishing** and **gloss**
- low **faradic efficiency** (<2%)



Solution 2

- good **adhesion**
- high **efficiency**, superior to deposition from Cr(VI) (**20-36%**)
- higher surface **roughness**
- **matt** appearance



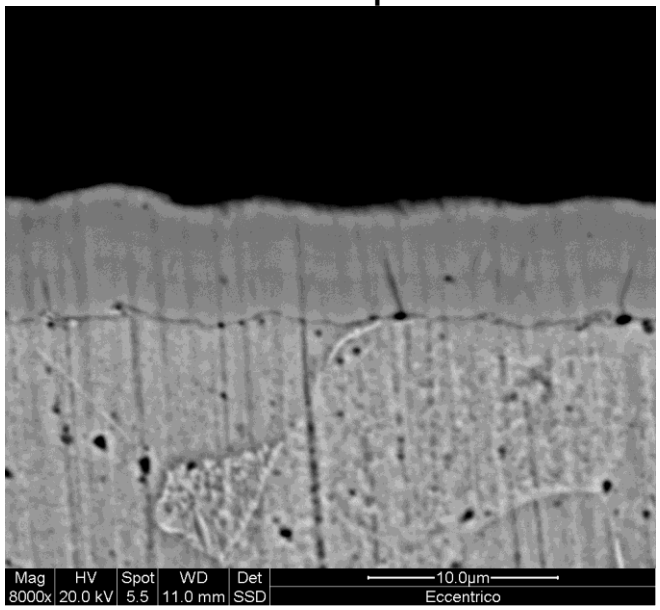
ELOCTRODEPOSITED COATINGS

RESEARCH CENTRE: Dipartimento di Ingegneria dei Materiali e dell'Ambiente, UNIMORE

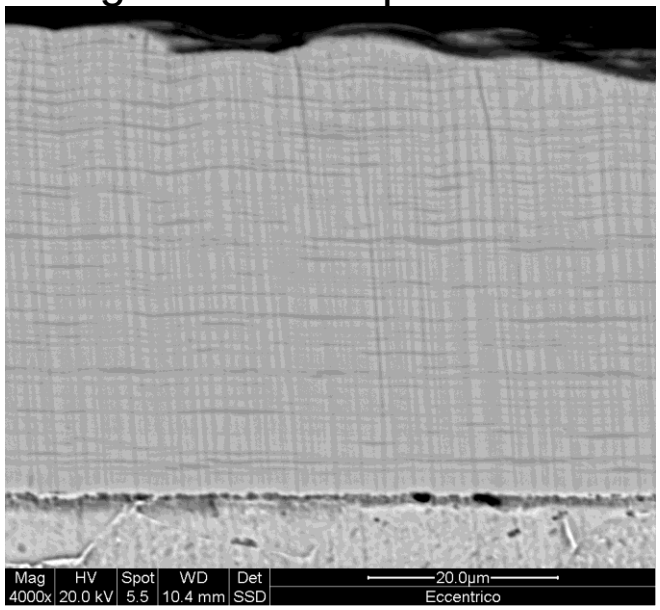
OPTIMIZATION OF ELECTRICAL PARAMETERS → IMPROVEMENT OF THE RESULTS

Pulsed current under galvanostatic control allows to obtain the best results with solution 2

Low current deposition



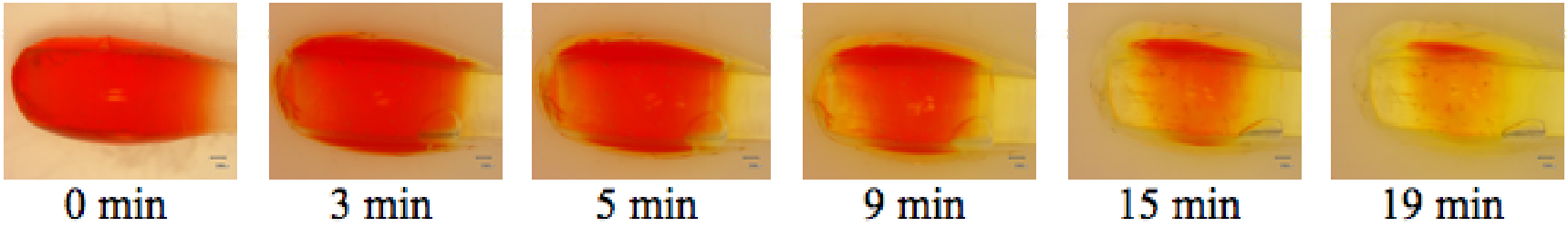
High current deposition



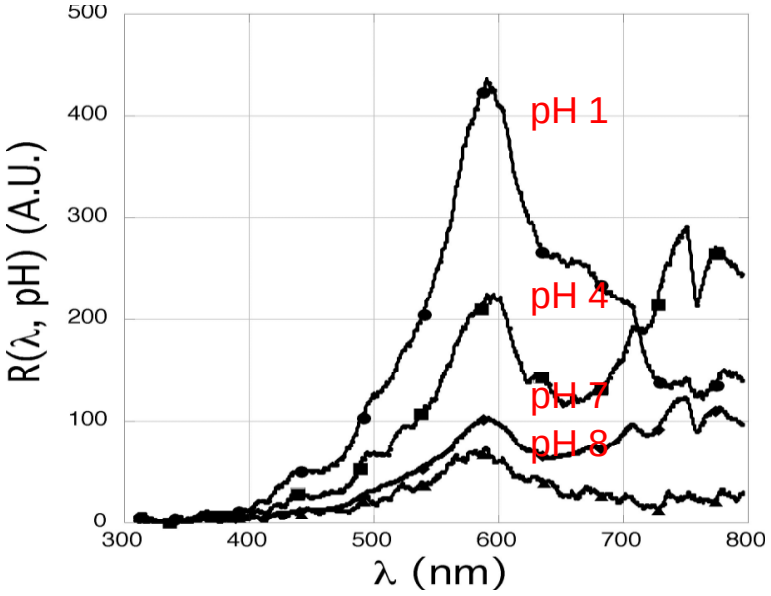
- good **adhesion** to substrate
- **no defects** (transversal cracks)
- good cohesion of the layers deposited during the different pulses
- improvement of **surface roughness**
- high hardness (always > 1100 HV)

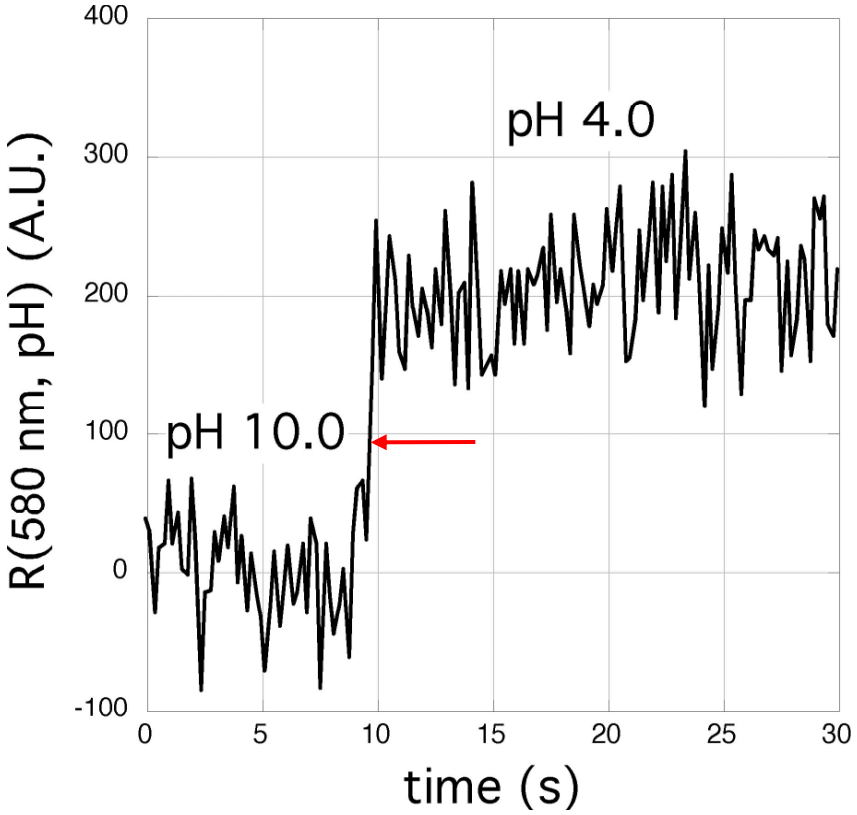
MATERIALS FOR OPTOELECTRONIC APPLICATIONS

OPTICAL SENSORS FOR pH, pCO_2



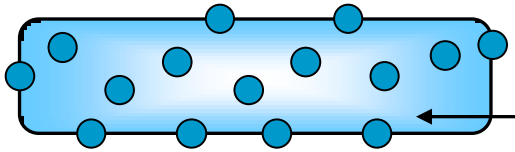
hybrid organic/inorganic nanocomposite obtained by sol-gel process





ANTIMICROBIAL COATINGS – ACTIVE PACKAGING

ACTIVE BY CONTACT

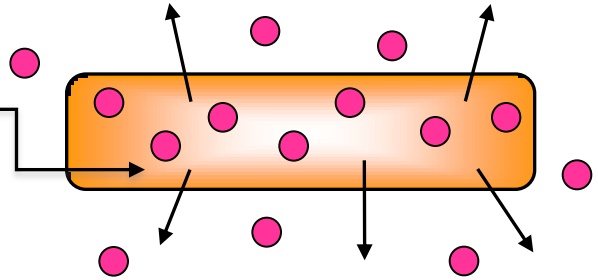


antimicrobial agents covalently bonded to the polymer matrix

quaternary ammonium salts
polymers with antimicrobial mojeties

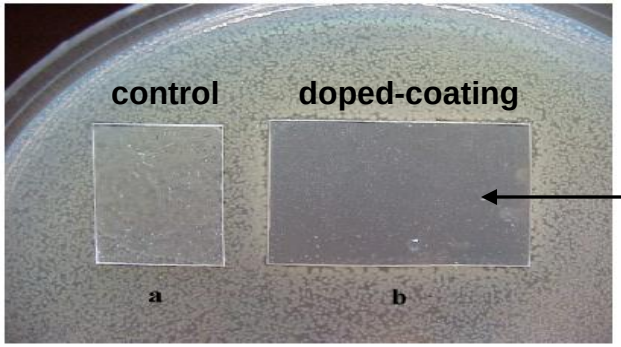
polymer matrix

ACTIVE BY DIFFUSION



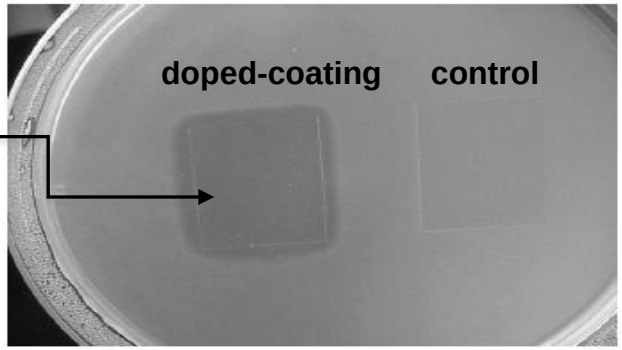
inclusion of antimicrobial agents into the polymer

silver ions and NP
naturals substances
bacteriocins and bacteriocins pruducer
living bacteria



antimicrobial activity **in contact** with the coating

zone of NON-growth



antimicrobial activity **in contact and around** the coating

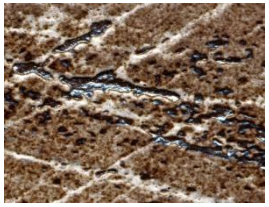
ENVIRONMENT AND SUSTAINABLE DEVELOPMENT

Characterization of **wastes**, **treatment** for reducing the **environmental impact**, **design/production** of **ecosustainable materials** with industrial technological transfer

- Inertization, recovery and valorization of inorganic/organic wastes
- Conventional and innovative (hot and cold) techniques for producing materials with low environmental impact for building industry and civil engineering (ceramics, glasses, glass-ceramics, bricks, composites, cement and pigments)
- Extraction of economically relevant components from wastes and/or residual products (ashes from incinerator plants, ceramic sludges, glass cullet, wastes from electrical and electronic equipments, wastes from agroindustrial field) by chemical and/or physical methods

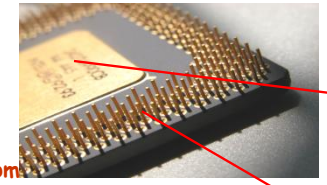
GLAZES WITH GLASS FROM ELECTRICAL/ELECTRONIC WASTE (RAEE)

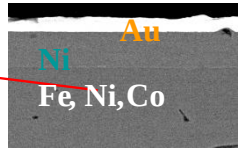


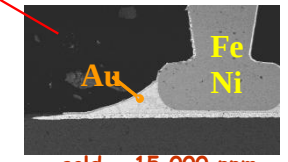


GOLD EXTRACTION FROM ELECRONIC BOARDS



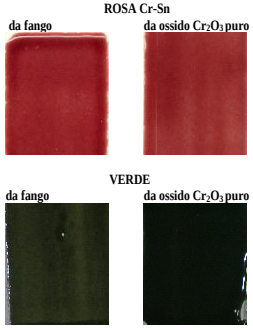






CERAMIC AND GALVANIC SLUDGES

PIGMENTS



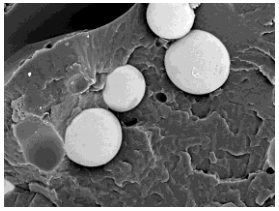
CEMENTS



INCINERATOR ASHES

GLASS-CERAMICS SINTER-CRYSTALLIZED





POLIMERS REINFORCED WITH GLASS FROM ELECTRICAL/ELECTRONIC WASTE (RAEE)

EXAMPLE OF INDUSTRIAL APPLICATION

Glazed stoneware tiles, with Ecolabel certification, manufactured with different size and thikness, containing glaze composed by 40% of **technical glass** from residues of **fluorescence lamps**

High quality product

Reduced environmental impact





