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DI PADOVA

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INDUSTRIALE

D I I I N F O R M A

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DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA

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Università degli Studi di Padova



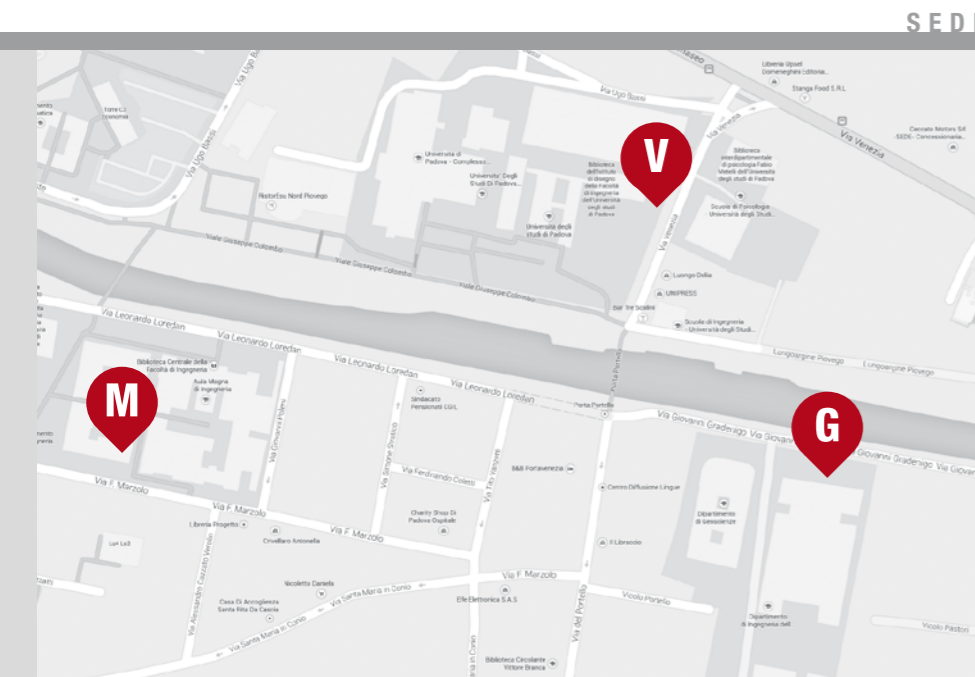
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Numero speciale per i Dottorandi di Ricerca

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Questo numero di DIInforma è dedicato agli studenti delle Scuole di Dottorato che lavorano nei laboratori del DII: grazie per il loro contributo e in bocca al lupo per il loro futuro!

A multi-fluid PSO-based algorithm for the search of the best performance of sub-critical Organic Rankine Cycles

To select the optimal working fluid for power output maximization, mono-objective single-fluid optimizations are usually conducted and a final fluid ranking based on the comparison between the results is created. To overcome this time-consuming approach, a PSO-based optimization algorithm (DS-ASD-PSO, Dynamic Search domain - Adaptive Search Diversification - Particle Swarm Optimization) was developed to include the choice of the best working fluid directly in the optimization procedure. As a consequence, during the optimization procedure, the search domain of each particle of the swarm was continuously and dynamically modified iteration-by-iteration due to the different vapour saturation lines of the chosen orking fluids. Multi-fluid optimization procedures were carried out considering 37 fluids simultaneously and source temperatures in the range between 80 and 150 °C.

The results, obtained with halved computational time, allowed to identify the dependency of the system efficiency on two relevant thermal parameters (fig. 1):

- the Jakob number related to the optimized cycle (Ja_{opt})
- the ratio between the critical temperature of the working fluid and the inlet heat source temperature ($T_{crit}/T_{s,in}$)

A new parameter Ω that combined the Jakob number and temperature ratio was proposed, whose minimization is correlated with the maximization of the system efficiency. Subsequently, a procedure to preliminary estimate Ω without the need to perform multi- or single-fluid simulation was developed and validated.

Such an approach would drastically reduce the number of attempts to find the best working fluid by carrying out detailed analyses on a restricted number of working fluids.

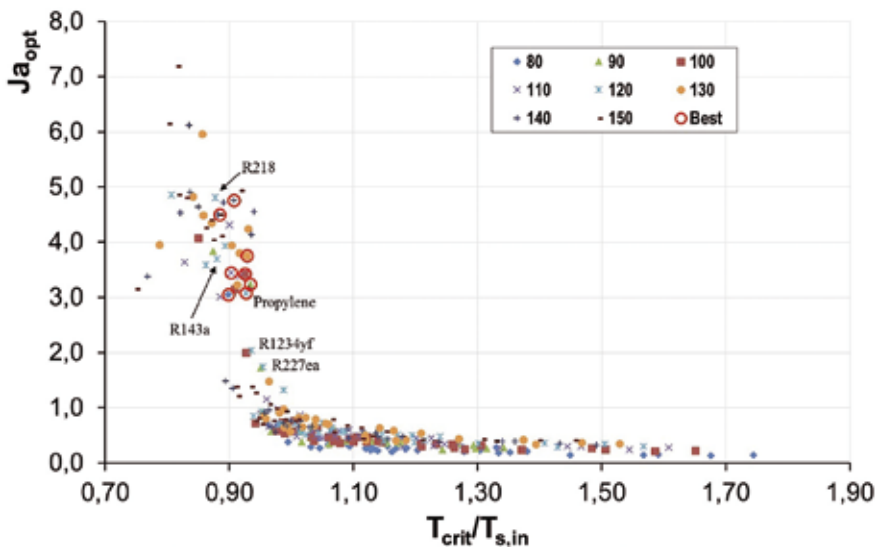


Fig. 1. Ja_{opt} as a function of $T_{crit}/T_{s,in}$ ($T_{s,in} = 80 \div 150^\circ C$).

The red circles identify the best performing fluids.

TES - Macchine a Fluido e Sistemi Energetici

Energetic Engineering



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Main research topics:

- Design and management optimization of energy systems by means of multi-criteria methods, Life Cycle Assessment (LCA)
- Optimal design and management of hydro and pumped-hydro power plants
- Design and optimization of hydraulic and wind turbines (VAWT and HAWT)
- Cavitation, instability and pressure pulsations in turbomachines at design and off-design operation conditions
- Gas turbines: development of numerical codes for performance prediction
- Aerodynamic optimization of rotors of helicopters and of high efficiency profiles isolated and detached

M.A.R.T.E.S. Group
 (Modeling, Analysis and Research
 in Turbomachinery and Energy Systems)
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Aerodynamic Design and Experimentation of Industrial Axial-flow fans

The research activity deals with the aerodynamics of axial-flow fans for industrial applications.

Fans are one of the most widely diffused machine, finding applications in several industrial fields from air conditioning to tunnel ventilation. According to this wide diffusion, these machines are responsible for consuming a relevant amount of the daily global energy.

In spite of a long history of fan applications (the first axial fan appeared in 1827 in Paisley, Scotland for mining operations) a comprehensive aerodynamic design method for machines featuring constrained dimensions and/or rotor speed is still missing. Both these constraints are typical for fans, being these machines commonly employed in human environments with limited space and low noise emission requirements.

A way to overcome these limitations is designing the fan rotor according to different aerodynamic distributions, to increase the performance capability of the usual iso-energetic design method (generally known as free-vortex design). This solution increases the design complexity however, while the fan blade shape changes according to the selected aerodynamic distribution (see Fig. 1). The main issue regarding this solution is the absence in the literature of clear indications for selecting a particular aerodynamic distribution and which are the advantages or drawbacks in terms of fan performance and efficiency.

A relevant achievement of the research activity has been the identification of the suitable operating condition of each vortex distribution for rotor-only axial fans. The experimental maps presented in April 2017 at the XII European Turbomachinery Conference suggest that fans designed with the iso-energetic free-vortex distribution achieve low performance but with high efficiency. On the contrary, Forced-Vortex fans achieve high performance at lower efficiency and can be used at higher flow-rates, while the Arbitrary-vortex geometries (see again Fig. 1) feature intermediate characteristics between the previous classes. These features make Forced-vortex fans suitable for applications with constrained dimensions and speed (e.g. for heat-exchanger external units).

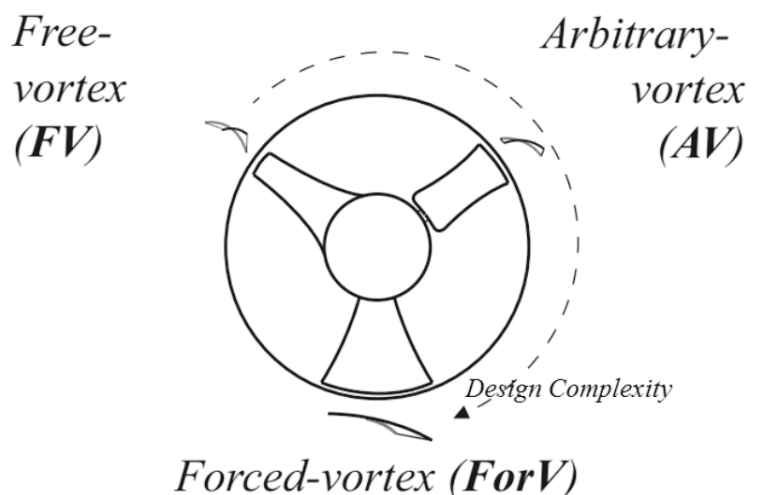


Fig. 1. Fan's blade shape according to the design Vortex criterion.

Main research topics:

- Energy systems
- Turbomachinery, combustors and internal combustion engines

Bioinspired multilayer structure made of silk-titanates nanocomposite as platform for humidity sensing

Nature is a great source of inspiration for scientists and engineers to design and fabrication of functional optical devices. Many animals and plants present a structural coloration, which is caused by interaction of light with periodic structure, usually used in camouflage or to transmit information. In many cases these structures have a stimuli-responsive behavior, which results in a reversible change of structural coloration in response to the surrounding environment.

Inspired by the cuticle of *Hoplia coerulea* beetle, we developed a multilayered structure that can sense the environmental humidity with a similar mechanism and transduces the humidity in a colorimetric scale.

The two materials used in this work are the silk fibroin, derived from *Bombyx mori* cocoons, and titanate nanosheets (TNSs), a novel 2D materials. Thanks to high transparency, mild processing condition, associated with biocompatibility and biodegradability, silk fibroin has recently emerged as good candidate for the fabrication of optical interfaces and devices.

Regenerated silk presents a refractive index of 1.55 at 500 nm, so in order obtain the refractive index contrast in the multilayered structure, pure silk was combined with a high refractive index silk:TNSs nanocomposite. TNSs are 2D crystals of sub-stoichiometric TiO₂ that were chosen because of their small size, high refractive index and water dispersability, which makes the integration with silk processing very easy to implement.

The multilayered interference structured was fabricated through a simple layer-by-layer deposition of the water solutions of both materials by spin coating on a glass slide. The optical properties in response to changes in the relative humidity were characterized and the sensing mechanism was investigated by simulations. The fabricated structure showed very good sensors characteristics, such as a sensitivity for a wide range of RH (from 10% to 80%), a low hysteresis, a very stable and reproducible response and a long-term stability.

In Figure 1, it is shown a schematic illustration of the bioinspired design of the stimuli-response film.

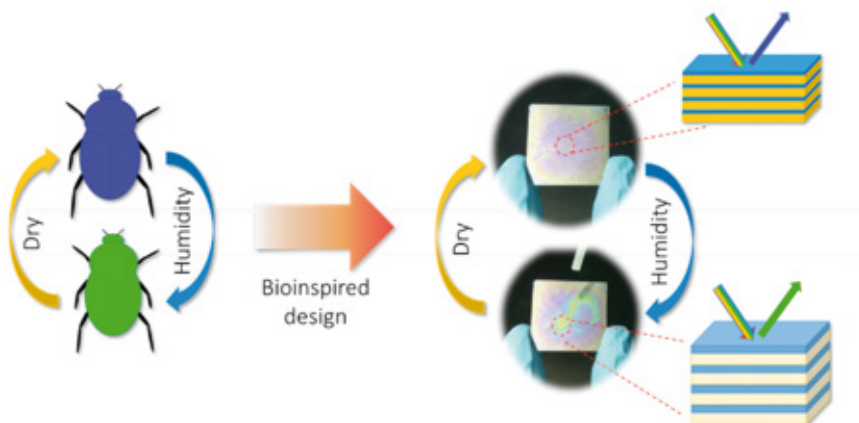


Fig. 1. Multilayer film inspired to the beetle, showing a colorimetric stimuli-response when exposed to humidity.

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Main research topics:

- Plasmonic gas sensor
- Nanocrystalline Inks
- Nanocomposites for chemical sensors

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Centre for Energy Economics and Technology
"Giorgio Levi Cases"



Main research topics

- Electric vehicles (wireless charging, conductive charging, propulsion drives, AC wheel motors, storage devices)
- Semiconductor power systems (solid-state transformers, grid-connection of energy renewable sources, power converters, electric power conditioning, AC motor drives)

Dynamic Wireless Charging of Electric Vehicles

Dynamic Wireless Power Transfer (DWPT) is a technology which can be employed to charge the battery of an Electric Vehicle (EV) while it is in motion, getting the required power wirelessly from a stationary electrical supply system. In a DWPT system, either a part or the overall power required by the EV is provided by the external power supply, and this permits to reduce the size and the weight of the battery pack installed into the vehicle. As a consequence, the performance increases, the cost is reduced and, at the same time, the problem of the limited range of the today available EVs is overcome.

A typical DWPT system comprises one (or more) transmitting coil(s), usually named track, which is (are) buried into the highway pavement, and one receiving coil, known as pickup, installed under the EV chassis. The base principle exploited by the DWPT systems is the electromagnetic induction: the track, supplied with an high-frequency current, creates in the surrounding space a time-variable magnetic field which links the pickup, thus inducing a voltage across its terminals that is suitably conditioned to charge the battery.

In the laboratory of Electric Systems for Automation and Automotive (ESAA), extensive research has been done both for the Static Wireless Power Transfer (SWPT), namely when the EV is parked above the transmitting coil, and the DWPT systems, dealing with the hot topics of these technologies, ranging from the theoretical aspects to the practical issues. For this latter purpose, the SWPT prototype shown in Fig. 1 has been implemented (the prototype is easily extendable to cope with the dynamic charging).

My research activity is focused on the dynamic charging and, in particular, covers (but it is not limited to) the modeling and the control of the DWPT systems. The control of a DWPT system is a difficult task, since it involves high-frequency quantities and varying parameters, therefore, the availability of an accurate mathematical model is required to design the controllers that maintain the system stability.

The main result of this activity is the development of a new modeling method which provides an easier implementation with respect to the traditional ones, without losing accuracy. The validity of this method can be seen in Fig. 2, where the output of the model matches very well with the envelope of the track current obtained from the simulation of the whole system.



Fig. 1. SWPT prototype set up in ESAA lab.

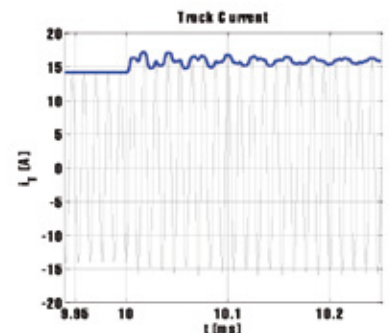


Fig. 2. Validation of the new modeling method.

Vertically-aligned mesoporous silica films by sequential electrochemically assisted self-assembly

Nowadays, two robust approaches are available to generate highly ordered silica films with mesochannels perpendicular to the underlying support:

- the Stober solution growth process;
- the electrochemically assisted self-assembly method;

The electro-assisted self-assembly (EASA) method combines the electrochemical interfacial surfactant templating (i.e., assembly of amphiphilic molecules under potential control) and electrochemically assisted sol-gel deposition of the silicate phase [1], in a self-assembly growth process. It involves the cathodic polarization of an electrode immersed in a hydrolyzed sol solution containing the silica precursor (e.g., tetraethoxysilane, TEOS) and a surfactant template (i.e., cetyltrimethylammonium bromide, CTAB), in order to generate the hydroxide ions that are necessary to catalyze polycondensation of the precursor species and induce the formation of transient surfactant hemimicelles around which the silica film is growing in the form of hexagonally packed one dimensional channels of about 2 nm in diameter perpendicularly to the electrode surface.

In figure 1, the possibility to get films with larger thicknesses, by developing a sequential EASA method (multilayer technique) is shown. The pore are aligned from one layer to the other and the orientation is preserved

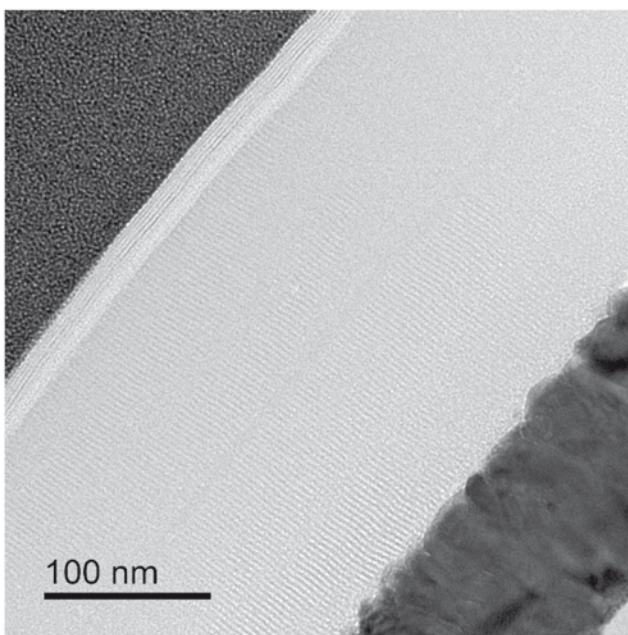


Fig. 1. Multilayer of vertically-aligned mesoporous silica

[1] C. Song, G. Villemure, *Microporous Mesoporous Mater.* 44-45 (2001) 679

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Main research topics:

- Palsmonic gas sensor
- Nanocrystalline Inks
- Nanocomposites for chemical sensors

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The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie Grant Agreement # 721185 (New-MINE, <http://new-mine.eu/>)

Main research topics

- Novel construction materials from inorganic waste and/or recycled glasses
- Monolithic and cellular glasses and glass-ceramics
- Nanostructured ceramic composites from preceramic polymers and fillers
- Advanced porous ceramic components
- 3D printing of ceramics
- Bioceramics from novel formulations and novel processing
- Porous geopolymers

Up-cycling of Vitreous Residues from Thermal Conversion of Landfill Waste in Highly Porous Glass-Ceramics

The EU-funded New-MINE project is aimed at the complete recovery of resources from excavated landfills. The approach is essentially based on plasma heating of waste, providing both gasification of organics, by pyrolysis (thermal treatment in non-oxidative atmosphere), and metal separation upon melting (under reducing conditions). Avoiding re-landfilling charges combined with the energy production from waste-derived gas ('Syngas') and the recovery of metals is undoubtedly attractive, but a true 'zero waste' condition and enhanced economical sustainability rely on the obtainment of added value products from the vitreous by-product of the plasma heating process ('Plasmastone'). Successful experiments have been conducted on highly porous glass-ceramics, by weak alkali activation of Plasmastone powder aqueous suspensions, followed by low temperature gelification (according to the formation of CSH gels, at 80 °C, see Fig.1) and sinter-crystallization at 800-1000 °C. An extensive foaming was achieved by intensive mechanical mixing of activated suspensions, before complete hardening, with the help of surfactants (Fig.2). Recycled glasses constituted fundamental additives, in order to promote the viscous flow sintering, upon firing, and limit the leaching of heavy metals (Fig.3). Optimized foams, with a porosity >75 vol %, exhibited a quite good compressive strength (>1.5 MPa).

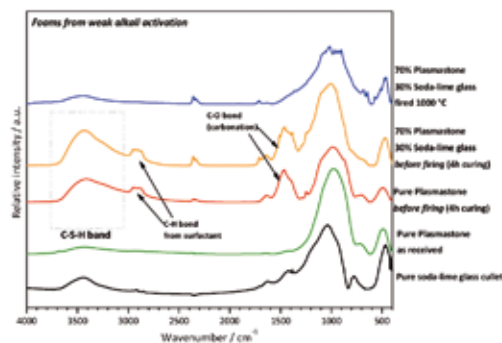


Fig. 1 FTIR spectra of Plasmastone-based material before and after alkali activation

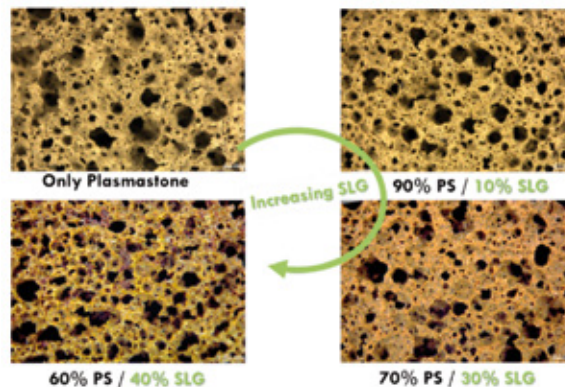


Fig. 2 Morphology of Plasmastone-based glass-ceramic foams

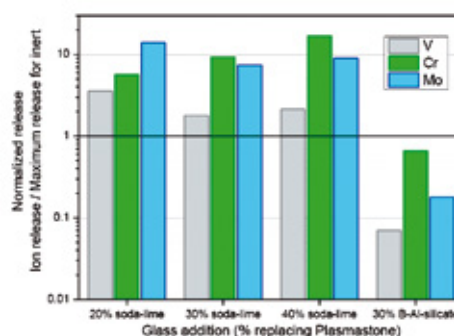


Fig. 3 Results of leaching tests [data normalized according to the leaching limits for inert materials (Austrian Recycling Building Materials Ordinance)] – B-Al silicate glass available from dismantled pharmaceutical vials

Functional Glass-ceramic Foams from 'Inorganic Gel Casting' and Sintering of Glass/Slag Mixtures

Glass foams have been recently manufactured according to a new method, based on alkali activation. Soda-lime glass suspensions, in alkaline aqueous solution, exhibit a pseudoplastic behavior (Fig.1), owing to progressive gelification at low temperature (80 °C), in turn due to the formation of hydrated calcium silicate compounds (CSH, see Fig.2). Before complete hardening, an extensive foaming may be achieved by vigorous mechanical stirring, with the help of a surfactant. Unlike in conventional glass foams, a sintering treatment, at only 700-800 °C, is applied after the foaming, to stabilize the cellular structures. The approach can be applied more complex suspensions, comprising also an industrial waste (from 10 to 30 wt% of the solid content), consisting of an iron-rich slag ('fayalite slag') from copper metallurgy. After foaming, glass/slag mixtures could be sintered at 800-1000 °C (Fig.3a,b). The mutual interaction caused an extensive crystallization (Fig.3c), with precipitation of Ca-Fe silicate and iron oxides (hematite and magnetite), promoting the mechanical properties (up to 2.3 MPa, with a porosity of about 80%). Leaching test confirmed the stabilization of pollutants, from the slag, in the final ceramics. Due to the separation of iron oxides, particularly magnetite, the newly obtained foams exhibited a ferrimagnetic behavior, that could be exploited in electromagnetic shielding applications (Fig.3d).

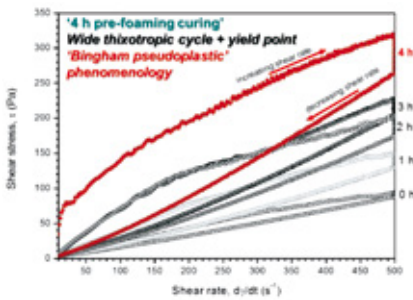


Fig. 1 Typical flow curves of soda-lime glass suspended (65 wt% solid content) in alkali activated aqueous solution (2.5 M KOH) after different gelation times, before mechanical stirring

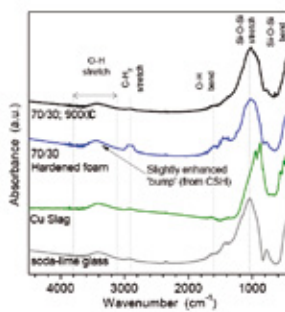


Fig. 2 FTIR analysis for mixtures before and after activation: evidence of 'CSH' bump after activation, lost after firing

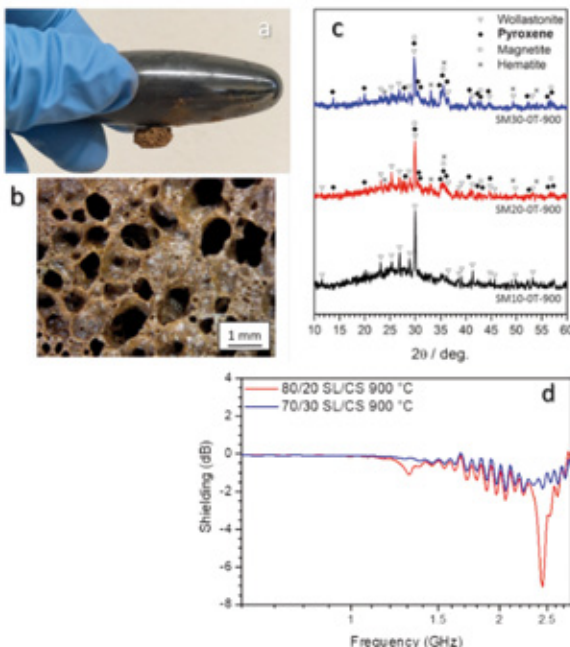


Fig. 3 Obtainment of ferri-magnetic glass-ceramics: a) foam attracted by a permanent magnet; b) micro-structure of a foam from soda-lime glass and Cu slag (20%), obtained by alkali activation/gel casting, fired at 900 °C; c) crystal phases as a function of Cu slag content; d) electro-magnetic shielding tests on selected foams

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The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 642557 (CoACH, www.coach-etn.eu)



More information on glass and glass-ceramic foams available at:
<http://www.sciencedirect.com/science/article/pii/S0955221917300262> (open access)
<http://www.mdpi.com/1996-1944/10/2/171> (open access)

Research also in collaboration with Prof. Daniele Desideri, in the framework of the DII Twinning Project 'MaVeRIF' (Materiali Vetroceramici da Rifiuti Industriali per Applicazioni Funzionali)

Main research topics

- Novel construction materials from inorganic waste and/or recycled glasses
- Monolithic and cellular glasses and glass-ceramics
- Nanostructured ceramic composites from preceramic polymers and fillers
- Advanced porous ceramic components
- 3D printing of ceramics
- Bioceramics from novel formulations and novel processing
- Porous geopolymers

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R.T. S.r.l. Unipersonale



Main research topics

- Preparation of inorganic thin films by vapour phase deposition techniques (MOCVD, PECVD, ALD) for protective, photocatalytic, biomedical, photovoltaic and self-cleaning applications.
- Preparation of nano/micro structured polymeric pattern and their functionalization.
- Wet chemical synthesis and characterization of oxides for photocatalytic applications.

Research and development of methodologies for the functionalization of titanium substrates for biomedical applications

Titanium and its alloys are widely used as implant materials in orthopaedic and dental applications, because of their non-toxicity, biocompatibility, corrosion resistance, and good mechanical properties such as high strength, durability, and light weight. In order to improve osseointegration, the titanium surface is generally functionalised. A typical methodology of surface modification, able to efficiently change the surface chemistry of a metallic implant, is the coating of the titanium substrates with layers of bioactive calcium phosphate ceramics (CPC). In this way it is possible to combine the metal mechanical strength with the biocompatibility and the bioactivity of the ceramics. Moreover, the implant roughness is critical for the osseointegration process. Titanium implants are usually processed in order to increase the surface roughness in a controlled way. Sandblasting and/or chemical etching are approaches commonly used.

With the aim of improving the adhesion strength between the Ti substrate and the CPC layer, the insertion of dense and compact ceramic interlayers is reported to be useful. Indeed, they improve the film to implant adhesion both reducing the thermal mismatch between the metal and the calcium layer and increasing the amount of -OH sites available. Among various ceramics, crystalline titania (TiO₂) has been extensively used as an inter-layer thanks to its well-known biocompatibility properties.

This PhD research activity deals with the development of a new synergic deposition route for the functionalisation of Ti dental implants, through their coating with suitable ceramic materials. In detail, a multi-step process is proposed, with the aim of obtaining a final composite material made up of a dense, compact and crystalline titania inter-layer, obtained through Metal Organic Chemical Vapour Deposition (MOCVD), and of a homogeneously spread discontinuous calcium phosphate ceramic (CPC) top-layer, with particular chemical composition, crystallinity and morphology, obtained by means of spray pyrolysis.

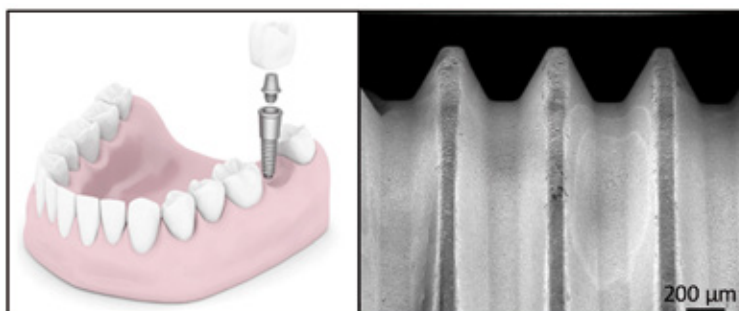


Fig. 1. Titanium dental implants.

Progetto AlpSporTec

Equipaggiamento sportivo esposto all'ambiente Alpino

Interreg V-A Italia-Austria 2014-2020

Cod. Progetto n. ITAT1027

CUP C92F16003830006

Il Dipartimento di Ingegneria Industriale dell'Università di Padova, con riferimento particolare al gruppo di Ingegneria dei polimeri, è partner nel progetto AlpSporTEC a fronte della pluriennale esperienza maturata nell'ambito dei materiali polimerici e dello sviluppo di materiali innovativi nanostrutturati.

Il progetto è coordinato dal Centro di tecnologia per sci e sport alpini di Innsbruck e tra gli altri partner trova Dolomiticert e l'Università di Innsbruck. Un team tecnico affiatato ed estremamente competente che si propone di trovare soluzioni innovative da applicare nel settore degli sport alpini, al fine di ridurre al minimo il rischio di lesioni, aumentando il comfort degli alpinisti.

Tre i WPs tecnici, con obiettivi molto ambiziosi:

- 1) Lo sviluppo di una fibra tessile per le corde da montagna, in grado di cambiare colore in funzione dell'esposizione ai raggi UV, segnalando quindi il degradamento delle caratteristiche meccaniche e la necessità di sostituire la corda per motivi di sicurezza.
- 2) Lo studio dell'attrito fra tessuti e superfici nevose e/o ghiacciate, con l'obiettivo di sviluppare un tessuto particolare che aiuterà a ridurre la velocità nel caso di cadute (es. nello sci alpino), riducendo così il rischio di lesioni.
- 3) L'aumento del comfort dell'abbigliamento sportivo utilizzato in montagna attraverso lo sviluppo e la ricerca di materiali tessili innovativi che offrono proprietà di termoregolazione favorevoli, garantendo al momento stesso la resistenza agli agenti atmosferici e la libertà di movimento necessaria per l'esercizio dello sport.

Il gruppo di Ingegneria dei polimeri è già nel pieno delle attività, con la caratterizzazione delle corde da alpinismo e con lo sviluppo di membrane nanostrutturate che presentano proprietà sia idrofiliche che idrofobiche mediante tecniche di elettrofilatura. Proprio a tale proposito è stato messo a punto nel corso di quest'anno l'impianto prototipale di elettrofilatura (electrospinning ed alectrospraying) per la produzione di multi-layers nanofibrosi polifunzionali;

Tutte le attività e gli sviluppi del progetto possono essere seguiti sulla pagina Facebook dedicata: AlpSporTec - Interreg V-A Italia Austria 2014 2020 e sul sito web: www.alpsportec.eu.

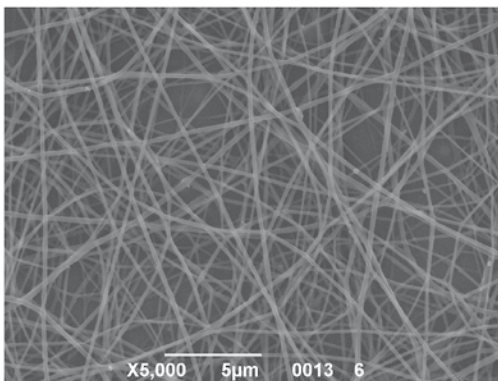
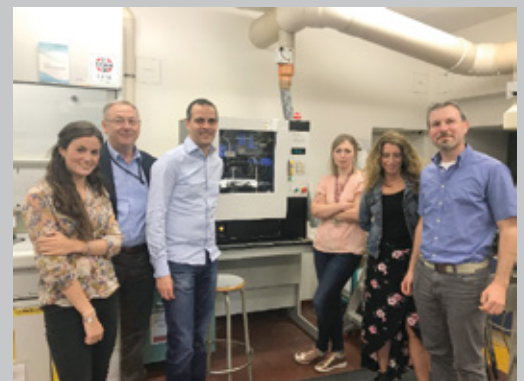


Fig. 1. Nanofibre prodotte via elettrofilatura: la base per lo sviluppo di tessuti innovativi.

Achievements

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I rappresentanti dei partner di progetto durante la visita al gruppo Ingegneria dei polimeri presso i laboratori del DII.