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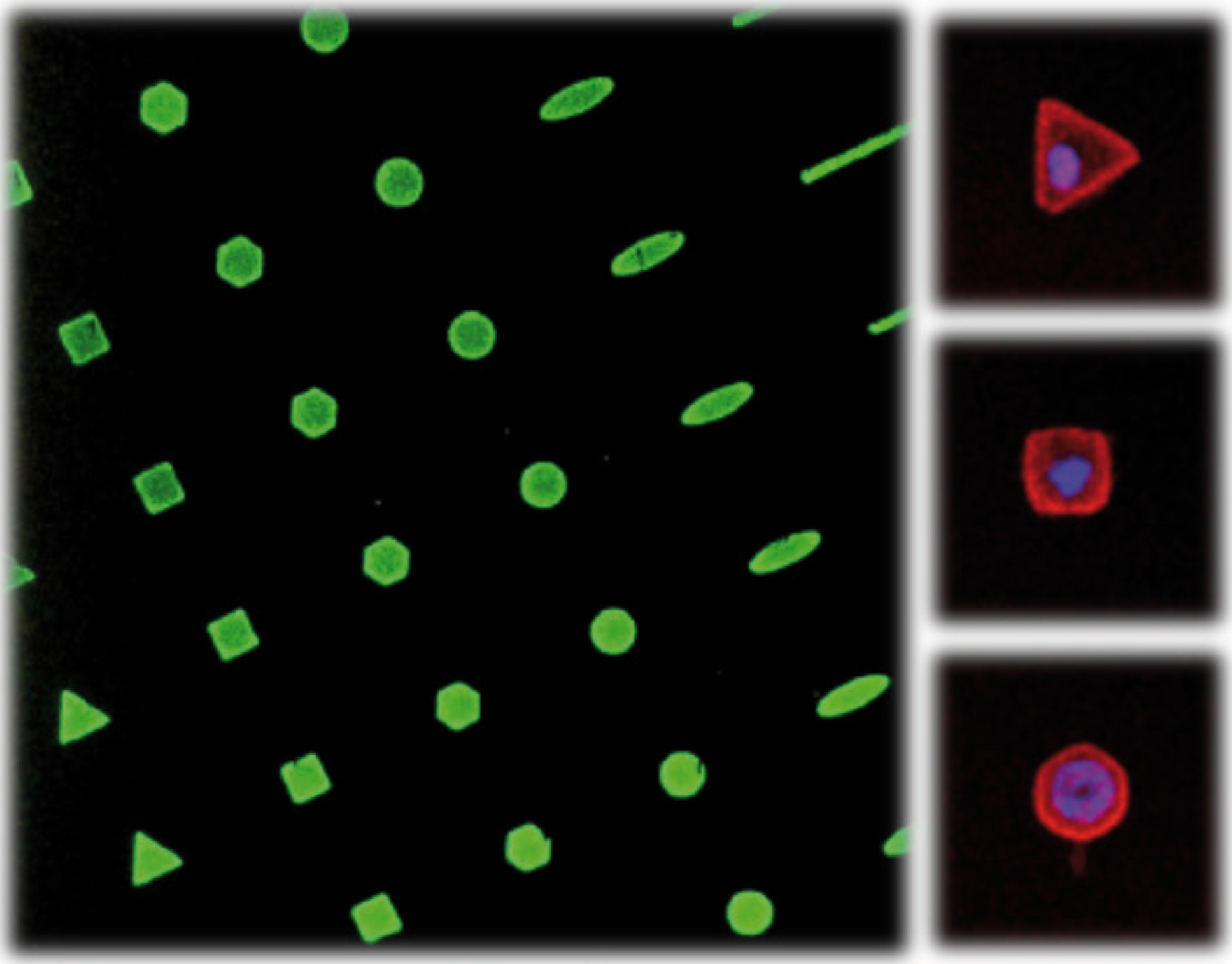
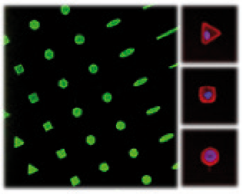
DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA

Università degli Studi di Padova

Dipartimento di Ingegneria Industriale





C O P E R T I N A

Micro pattern fluorescenti su substrato vetroso

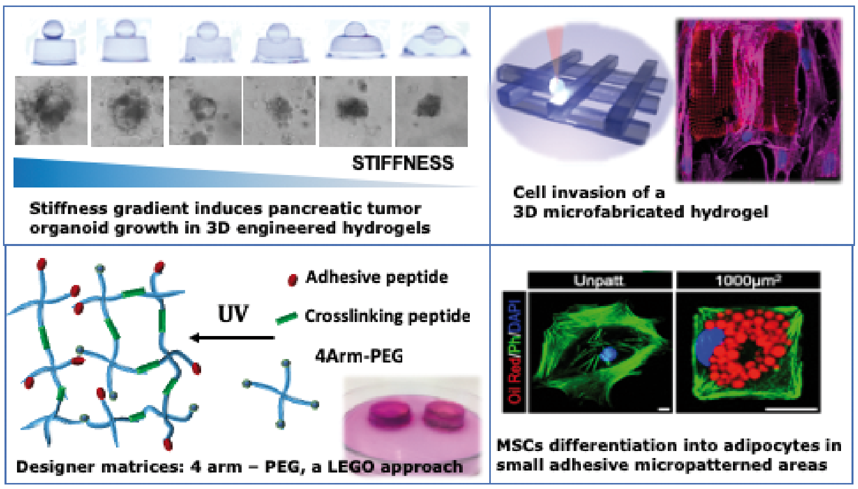
PAGINA

DIPARTIMENTO
DI INGEGNERIA
INDUSTRIALE

Biomaterials and engineered microenvironments for biomedical studies

In our lab we engineer chemically and physically defined biomaterials, in particular hydrogels, and we develop advanced microtechnology tools to generate 2D and 3D culture microenvironments. These culture systems are designed for stem cells regeneration and expansion, with the aim of recreating in vitro models which more closely mimic the natural microenvironment of human cells for disease studies, in particular cancer.
This research deals with mechanobiology, a multidisciplinary science in which biology must necessarily interlace with engineering and material science. In fact, mechanical signals are increasingly recognized as overarching regulators of cell behaviour, controlling stemness, organoid biology, tissue development and regeneration. Moreover, aberrant mechanotransduction is a driver of disease, including cancer, fibrosis and cardiovascular defects. In order to apply mechanical challenges, cells need to be exposed to chemically- and physically-defined tissue niches, made of hydrogels having "ad hoc" designed rigidity, mechanical properties and architectural features, for both 2D and 3D in vitro cultures.
Breakthroughs have been discovered using 2D hydrogels and micropatterns with defined and controlled physical properties such as stiffness and geometry respectively. These results go far beyond the limit of the classically preferred cell culture model, 2D cell monolayers cultured on adhesive rigid and flat plastic petri dish substrates. Moreover, building tissues for regenerative medicine applications heavily relies on next-generation tissue-engineered approaches, that aim to develop a new platform by which the cells of an individual patient can be expanded and regenerated growing as organoids, 3D outgrowths of stem cells that self-organize into miniorgans, representing copies of real organs, in defined laboratory conditions. This expands the possibility to study normal and diseased tissues ex vivo, with promise to understand disease mechanisms, to test drugs and therapies in unprecedented personalized medicine approaches.
This highly interdisciplinary research is carried out in collaboration with the Molecular Medicine Department of Padova, MBI (Mechanobiology Institute of Singapore), IIT (Italian Institute of Technology) IFOM (IFOM Istituto FIRC di Oncologia Molecolare).

Nature Materials, 17, 1063-1075 (2018)
Nature, 563, 265-269 (2018)
Acta Biomaterialia, 55, 373-384 (2017)



Research topic:
Materials

DII research group

HyMat

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Main research topics:
- Synthetic and natural Hydrogel materials for biomedicine 2D and 3D
- Microfabrication of biomaterials

Research topic:
Materials

DII research group
Polymer Engineering Group
(PEG)

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The research activity is carried out in collaboration with the PEG, Polymer Engineering Group.

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Main research topics:

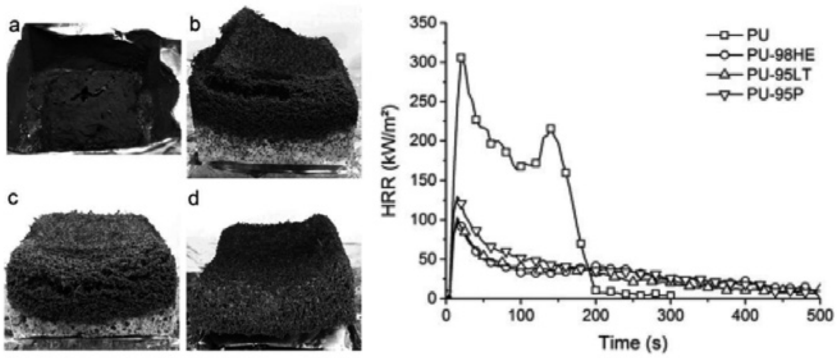
- Nanostructured membranes based on nanofibers
- High performance polymeric nanocomposites
- Thermal stability and fire behavior of polymeric materials
- Design and processing of polymeric materials
- Physical and chemical recycling of plastic materials

Expandable graphite in polyurethane foams: the effect of expansion volume and intercalants on flame retardancy

Expandable graphite (EG) belongs to the class of graphite intercalation compounds. These materials are formed by inserting atomic or molecular layers of a different chemical species as an intercalant between the layers of a graphite host material. Since 2002 EG is being widespread used as flame retardant in polyurethane (PUR) and polyisocyanurate (PIR) due to its capability to act as char that covers the burning surface, slowing the spread of the flame. Despite this, just few studies have dealt with the effect of EG properties on fire behavior but only in terms of the combined effect of expansion volume and EG size. In order to have a better understanding of EG role we have avoided this "coupling effect" by analyzing the fire behavior of different EGs with the same particle size. Specifically we have analyzed their retardancy effectiveness in PUR foams in terms of type of intercalant compound (sulfur- or phosphorus-based) and expansion volume (Table 1).

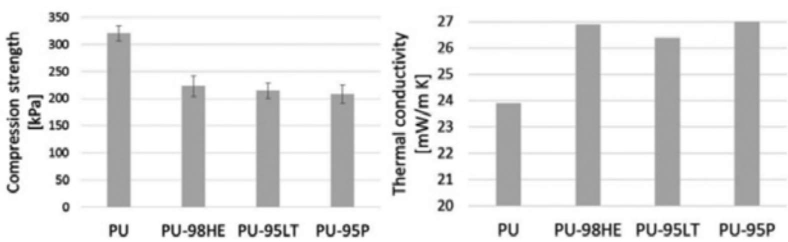
Table 1. Main properties of EGs used

Sample	Minimum expansion volume (cm^3/g)	Particle size
98HE	300	min 70% > 50 mesh
95LT	200	min 70% > 50 mesh
95P	200	min 70% > 50 mesh



The results have shown that both the two type of intercalants enhance the residue yield, induce a protective layer, and thus efficiently flame-retard PUR foams (Figure 1). However the expansion volume of the EGs had a surprisingly limited influence on the performance of the foams, at least in the range tested. The most important feature controlling the effectiveness of EG in terms of flame retardancy of PUR foams was the type of intercalant, with better performance of sulfur over phosphorus. The presence of EG affected the physical–mechanical properties of the foams; however, no significant effect of the expansion volume or intercalant type has been revealed on the physical–mechanical properties of the foams (Figure 2).

Figure 2. Compression strength (left) and thermal conductivity (right) of unfilled and filled PU foams



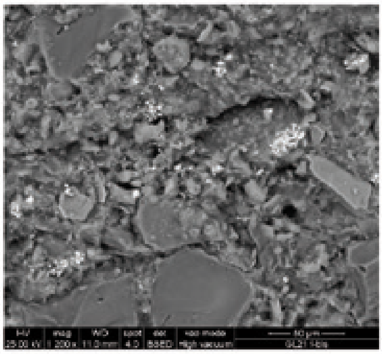
Dielectric composites with tailored magnetic nanoparticles

A series of new inorganic magnetic composites (IMCs) has been prepared to obtain magnetic materials with tunable thermal and mechanical resistance properties. Indeed, in the field of power inductive components, inductive heating and cooking, they may transfer energy with high robustness and excellent performance. Moreover, these materials may mitigate electromagnetic interference (EMI) at frequencies in the LF and MF band.

The composites (Figure 1) have been synthesized by using alkaline or acidic activation processes, carried out in the presence of commercial nanoparticles (isotropic and anisotropic Sr-ferrite). Three different inorganic matrices have been prepared by varying the type of activator, slag addition, water content, and aggregates.

The matrices prepared in alkaline conditions and the one in acidic ones will allow the investigation of the electrical properties, which are known to depend strongly on the activation conditions due to the different ionic content.

Figure 1: Sample of magnetic composite.

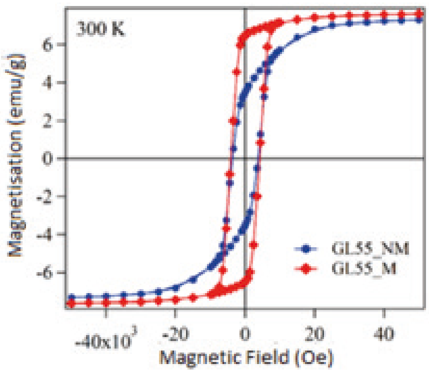


The SEM images (Figure 2) show that there is a noticeable tendency for magnetic particles to aggregate in the matrix. Isolated single magnetic particles are rare.

Figure 2: The particles of magnetic powder in the back-scattered electron SEM images of a sample obtained in basic conditions appear lighter than the matrix.

The hysteresis cycle (Figure 3) of the samples obtained under a magnetic field (M) is more square than that of the corresponding samples produced without the effect of the field (NM). This influences the value of the residual magnetization and therefore of the dispersed field generated by the sample.

Figure 3. The effect of the magnetization process during the solidification of the samples. Comparison of the magnetization cycles on M (field on) and NM (field off) samples with a nominal concentration of particles ~ 10%.



Research topic:
Materials

DII research group

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Main research topics:

- Magnetic nanoparticles;
- Inorganic polymers;
- Composite materials

Research topic:
Energy

DII research group

TES Research Group

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This research activities on energy recovery potentail and leakage reduction are carried out in collaboration with the University of Pretoria (South Africa) and with i@Consulting (Pty) Ltd.

In particular the following people were involved in the project:

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Department of Civil Engineering

Dr. Gideon Johannes Bonthuys
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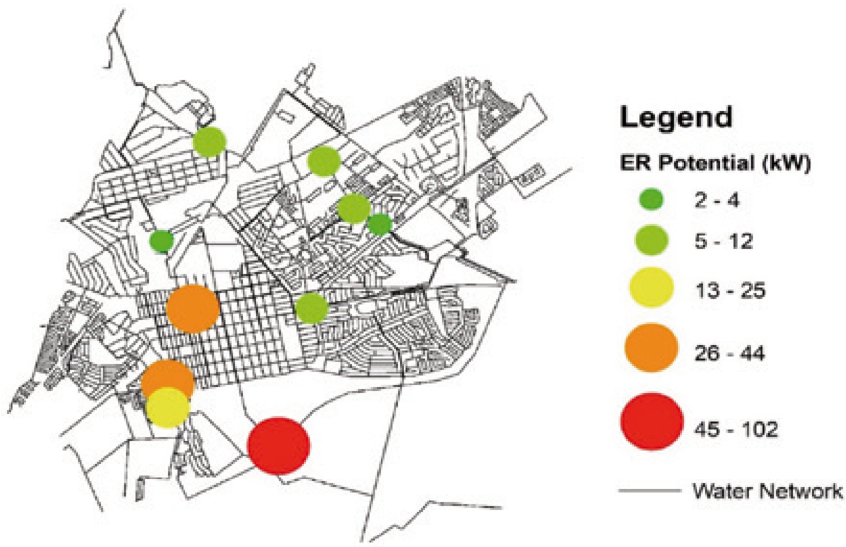
Main research topics:

- 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
- Design and management optimization of energy systems by means of multi-criteria methods, Life Cycle Assessment (LCA)
- Gas turbines: development of numerical codes for performance prediction
- Aerodynamic optimization of rotors of helicopters and of high efficiency profiles isolated and detached

Renewable Energy Recovery and Leakage Reduction in Water Distribution Networks

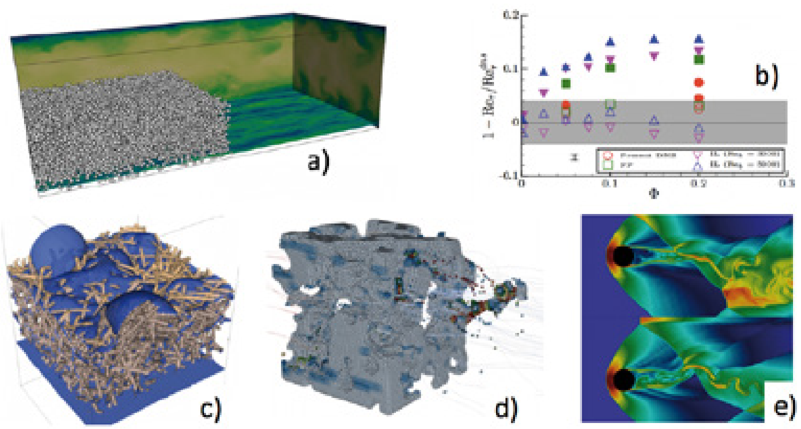
In a water distribution system, the pressure is generally managed and controlled by means of Pressure Reducing Valves (PRVs), dissipating energy in order to control the maximum admissible pressure in the system and to avoid rupture. The hydraulic grade line principle associated with a PRV is similar to that of a turbine. In both cases, a pressure drop across the component allows downstream pressure control. However, instead of dissipating energy, conduit hydropower plants allow for recovering energy and hence may potentially increase the sustainability and resilience of cities. The exploitation of this potential will contribute to the city's sustainability not only in terms of renewable energy recovery but also in terms of leakage reduction, since a reduction in pressure through conduit hydropower will also reduce water losses through leakages due to the direct proportionality of leakage to pressure.

The research carried out by the TES research group focuses on the water distribution networks with the aim of identifying the hidden energy recovery potential. In particular, The City of Polokwane, a local municipality within the Limpopo Province in South Africa, was considered. The municipal surface area covers over 5000 square kilometres and serves around 280 000 customer units, inclusive of residential and non-residential customers. A section of the Polokwane/Seshego regional segment was isolated as a District Metered Area (DMA) and modeled with the EPANET hydraulic modelling software hydraulic model. Standard demand patterns for the applicable levels of service were used for the 24h period simulation of the model. An energy recovery optimization algorithm was applied to the analysed district in order to identify the energy recovery potential. Several constraints were considered in the optimization procedure. Above all, the operating pressure was not allowed to drop under the operating pressure limits, fixed based on leakage control and consumers satisfaction. A decreased average operating pressure was achieved by energy recovery at the 10 locations with the highest conduit hydropower potential (see figure below)., resulting in a combined energy recovery potential of 264 kW. The reduction in operating pressure due to the energy recovery resulted also in a 4.2% reduction in potable water supply losses.



High Performance Computing as Research Tool in Fluid Dynamics

The research activity of the group focuses on high-performance computations of complex flows. These are characterized by chaotic and multiscale behaviors induced by their intrinsic non-linear dynamics leading to turbulence and/or shock-waves. Often their complexity is amplified by the presence of concurrent phenomena as in multiphase/reactive flows, porous media, fluid-structure interaction. The range of involved scales becomes huge, typically from microns (droplets, small vortices, pores) to meters (macroscopic size), which constrains usual computational approaches to rely on extensive models to make simulations affordable. However, the recent developments in supercomputers and efficient algorithms opened new perspectives to researchers in these fields. "Virtual" experiments can now be performed at the condition that minimal models are adopted so that the processes at all scales are directly simulated from first principles (DNS). Despite the high computational cost, these "virtual" experiments give access to an unprecedented view with all observables simultaneously available. The need to efficiently exploit the increasing computational power, running on hundred thousands cores in parallel makes this a truly multidisciplinary field, at the intersection of numerical analysis, fluid dynamics and computer science.
The present group is active both in developing original methods and collaborating with other groups to simulate complex fluid problems. Within the international collaboration with TU-Delft (prof. Breugem) and KTH Stockholm (prof. Brandt), we performed the largest "virtual" experiments of turbulent particle-laden channel flow (ack.: European project PRACE DILPART: 32M core-hours, i.e. 3652 years single-core). From the dataset produced we have proposed new scaling laws relating the friction and flow rate for the wall-bounded turbulent flow of particle suspensions (Fig a,b). Among the collaborations with other groups at DII, we mention the computational studies on porous electrodes of Fuel Cell and Redox Flow Battery (prof. Guarnieri group;Dr. Maggiolo), aiming to understand how the flow through the electrode micropores affects the battery performance. In particular we have characterized the effect of the pore/fiber orientation on the effective diffusion and reaction using a in-house-developed software (based on the Lattice-Boltzmann Method) able to simulate multiphase flows through micropore networks (Fig c).
Moreover, we are developing an innovative algorithm for fluid-structure interaction problems considering solid damages (prof. Galvanetto group), e.g. hydraulic fracturing (Fig d), and a state-of-the-art software to simulate turbulence/shockwave interaction in complex geometries (prof. Benini group), a critical issue in transonic turbines and aerodynamics (Fig e). To conclude, the group is active in developing high performance computing tools for complex fluid problems. We are convinced that in the coming years this field is going to have an increasing impact in the industrial research.



Turbulent suspension flow: a) snapshot, b) new scaling law (open symbols); c) Porous media flow; d) Hydraulic fracturing; e) Supersonic unsteady cylinder flow.

Fluidodinamica
Fluid dynamics

DII research group

Fluid dynamics

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The research has been carried out in collaboration with:

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Prof. W.P. Breugem (TU-Delft, NL)
Dr. A. Trovò & Prof. M. Guarnieri,
Prof. E. Benini,
Prof. M. Zaccariotto,
Prof. U. Galvanetto (UP)

Main research topics:
- Multiphase flows
- Computational methods for complex flows
- Fluid-structure interaction
- Supersonic flow modeling
- Porous media flow
- Spray and Combustion
- High Performance Computing

Research topic:

Mechanical systems engineering

DII research group

Harvesting- MMSA

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Rain-drop energy harvesters

Rain-drops impact the ground with a finite velocity, hence they have kinetic energy that usually is lost and in extreme cases can cause damages. In recent years there has been a great development of energy harvesting technologies based on piezoelectric devices and some researches have suggested to exploit the impacts of rain-drops on piezoelectric layers to generate electric energy. Both the possibility of harvesting small amounts of energy for feeding autonomous sensors or small electronic devices and the possibility of harvesting large amounts of energy in tropical countries with large rain rate have been analyzed.

A rain-drop harvester is a multi-physical dynamic system excited by a series of impacts. Experimental results obtained with actual and simulated rain showed that the rain-drops generate series of well-separated force impulses on the harvester, and that the presence of a water layer on the harvester surface may have positive effects on harvester performance.

This research deals with a novel rain-drop harvester equipped with a rectangular container that creates a small pool that is used to collect the rain-drops, see figure 1.

Figure 1. . Rain-drop harvester.

This design makes the functioning of the harvester more regular, since the rain-drops impacts always take place on a water layer with a minimum depth.

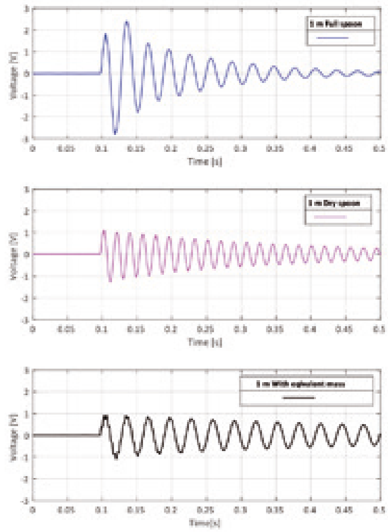

Figure 2. Voltage generated with and without the water layer.

Experimental tests carried out in the laboratory of Mechanical Vibrations of DII with simulated rain show that the presence of the water layer increases the conversion form kinetic energy of the impacting rain drop to electrical energy, see figure 2. Multi-physic dynamic models are developed to explain the increased efficiency of the harvester. Numerical results show that, the added mass of the water in the container reduces the efficiency of the vibrating system, but largely changes the impact dynamics. The second effect is dominant and leads to an increased collection of energy.

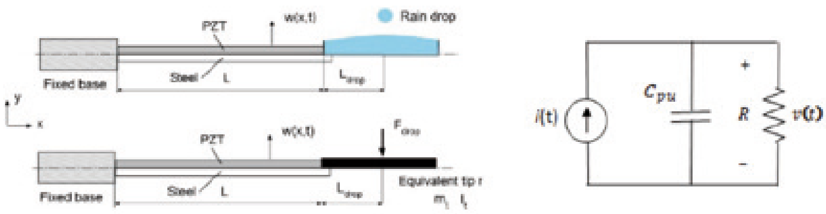

Figure 3. Multi-physical dynamic model.

Main research topics

- Energy harvesting
- Vibrations generated by impacts
- Multi-physics simulation
- Experimental mechanics

Low temperature pasteurization of high nutritional food products

In the Supercritical Lab we study the potential of supercritical CO_2 as alternative technology for the preservation of high value food product. Thermal pasteurization is commonly used to increase the shelf life of food, however the high temperatures cause a decrease of the product quality in terms of nutritional and sensorial aspects. High pressure CO_2 can be used as alternative to pasteurize the food at low temperature. CO_2 at the supercritical state has bactericidal property that allows to inactivate spoilage and pathogenic microorganisms. The low process temperatures (< 45 °C) maintain the chemical-nutritive properties of the raw product making it suitable to produce high value products. The process can be combined with high-power ultrasounds, leading to a synergistic effect on the inactivation of microorganisms. We are currently working on the low temperature pasteurization of pomegranate juice. The high antioxidant activity of pomegranate juice gives it anti-inflammatory, antiviral and anticancer properties. We have optimized the process parameters (temperature, time and pressure) necessary to obtain a total inactivation of the natural present microorganism in the pomegranate juice. Chemical and nutritional analyses have shown a maintenance of the polyphenolic content and antioxidant activity after the supercritical process.

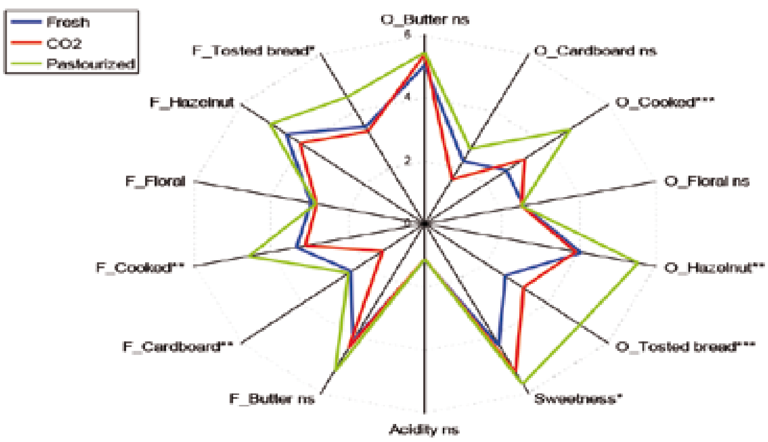

*Figure 1. Spider plot for the sensorial attribute of an high nutritional juice: comparison between untreated, thermal pasteurized and CO2 pasteurized juice. For each sensory attribute the name (O: odor; F: flavor) and its significance are reported (ns: not significant at 5%; *: 5%; **: 1%; ***: 0.1%).*

Research topic:

Industrial processes and products

DII research group

Supercritical Gruop

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POR FSE 2014-2020 Regione del Veneto "Pastorizzazione a bassa temperatura di succo di frutta ad alto valore nutritivo" 2105-60-11-2018.

Project sponsored by European Social Fund (FSE) & European Regional Development Fund. Increasing the preservation and safety of fresh products by innovative food processing technologies, CARIPARO Visiting Project 2018 WHOLE FRESH Development and optimization of low temperature pasteurization technologies to increase the shelf life of fresh food products - COSID2018

Main research topics

- Optimization of high pressure CO_2 process for low temperature food pasteurzation
- Effect of the combined process of supercritical CO_2 and high power ultrasounds
- High pressure CO_2 process for food drying
- Batch and continuous pasteurization/drying of solid food products
- Investigation of CO_2 microbial inactivation mechanism
- In situ and on-line analysis of food quality under CO_2 pressure
- Microbial analysis of food products after pasteurization treatment

Research topic:
Industrial processes and products

DII research group
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Collaboration

This work was carried out as part of a project supported by:
UNIFRONT Spin-off of the University of Padua.

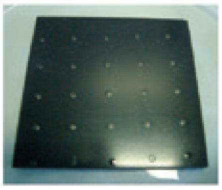
EFA (European Fighter Aircraft)

Main research topics:

- Technologies against threats posed by environmental events and trends to individuals, communities or nations.

CWA decontamination of EFA's materials

The EFA (European Fighter Aircraft), or Eurofighter Typhoon, is a four European nations twin-engine, multirole aircraft, designed and built by a consortium of three separate partner companies: Alenia Aeronautica, BAE Systems, and EADS working through a holding company Eurofighter GmbH. The aircraft has entered into service with the UK Royal Air Force, the German Luftwaffe, the Italian Air Force, the Spanish Air Force and the Austrian Air Force.
Concerning the operability of the aircraft in a CW environment, a joint commission of experts of the four partner countries, on the basis of chemical and physical properties, sorted all the metallic and non-metallic materials used in aircraft construction in four different lists, each one with different levels of chemical agents penetration resistance characteristics: 1. Poor, 2, Sufficient, 3. Good, and 4. Excellent.
The purpose of the research was the efficacy evaluation of the new decontamination concept, designed for "thorough decontamination" of "sensitive equipment", on ten different materials belonging to the list 2 (sufficient).
"Sensitive equipment" is generally difficult to decontaminate due to their construction characteristics, component materials, and location. Humidity and corrosive decontamination products may damage some of these materials. Moreover, weaponized chemical and biological agents are designed to resist decontamination by penetrating the surfaces they touch.
The CBRN decontamination system has been developed with the purpose of satisfying the following objectives: ready-for-use system, active for different CBRN agents, as well as any other substance that may contain them, no liquid form in order to avoid spread of contamination, no chemical reaction on the surfaces except removal of agents, detoxification/disposal of the decon residue remotely, useable virtually on all surfaces (material/morphology) without causing damage, even after multiple application cycles, eco-friendly, suitable for military and civil application, long life span, easy to handle and store.
Ten different materials of group 2, commonly employed in the internal part of aircrafts, have been chosen by expert of the consortium.
Samples are square cut pieces of the previously reported materials (5×5 cm = 25 cm^2).
The contamination was performed to realize a HD concentration of 2g/m^2 (contamination 10 times higher than specific NATO Document, (0.2 g/m^2).
CBRN decontamination system is based on a multiphase aerosol system contained in a pressurized metal canister and ready to use. The decontamination procedure-employed in the laboratory was performed by the defined "decontamination cycle".



For the more sensitive materials the "liquid" drops of HD disappear leaving a swollen surface after only a few minutes from placing HD on the sample.
Figure Oil-resistant nitrile rubber (type 2001) after 1 minute from the contamination.

The results obtained can be used to show some fundamental aspects of the mechanism by which the CBRN decontamination system acts, helping to understand the effects influencing the decontamination process efficiency. For this purpose it would be useful to focus on the differences between the CBRN decontamination system decontamination yields and the solvent-wash ones.
CBRN decontamination system treatment gave a greater decontamination performance for all tested materials if compared with solvent-washing.
The greatest differences are related to the more sensitive materials that are the ones with less resistance to the HD penetration after 30 min of contact time.
A reasonable interpretation of these data is that the HD penetrated into the material is effectively extracted by CBRN decontamination system proving the high CBRN decontamination system extraction capability. The CBRN decontamination system capacities to extract the toxic from the more resistant materials, in which the chemical aliquot remaining over the surface is the most of the total contamination amount, are partially hidden by solvating process that is the primary process by which the toxic is removed. After all, the good solvent power shown by CBRN decontamination system in these cases, together with the concomitant extraction activity, that manages to remove the chemical residual traces not eliminated by the solvent action, achieves excellent decontamination yields.

Una barca completamente riciclabile: il progetto del team Métis Vela

Il team Métis Vela, squadra velica dell'Università di Padova composta unicamente da studenti, sotto la guida del professor Andrea Lazzaretto si occupa da più di dieci anni della progettazione e della costruzione di skiff per competere con squadre di altre università italiane nella regata annuale 1001Vela Cup. La gara, oltre che sul piano sportivo, si gioca anche sul piano tecnologico. Le barche devono soddisfare regole precise: il 75% dello scafo dev'essere costituito da materiale proveniente da fonti naturali o, in alternativa, essere completamente riciclabile.

Non è una costrizione banale: la maggior parte dei natanti da regata in circolazione è realizzata con resine termoindurenti e fibre di vetro o carbonio che, per loro natura, garantiscono eccezionali prestazioni, ma non hanno un buon impatto sull'ambiente, soprattutto perché il loro riciclo è problematico o troppo oneroso.

Il team decide di contattare un'azienda francese, la Arkema, che ha finito di sviluppare una resina termoplastica che promette prestazioni simili alle epossidiche ma col vantaggio di essere riciclabile. Elium, questo il nome, è basata su polimetilmetacrilato il cui indurimento è reso possibile grazie a perossido di benzoile in polvere. La natura termoplastica del PMMA garantisce la possibilità di avviare eventuali prodotti a fine vita a processi di riciclo.

Lo scafo e la coperta della barca sono stati prodotti per infusione sottovuoto, garantendo una elevata frazione volumetrica di fibra, così da contenere il peso totale. Uno dei problemi maggiori incontrati durante l'infusione è stato l'elevato innalzamento della temperatura dovuto al processo esotermico di polimerizzazione: picchi di 180°C hanno reso necessarie precauzioni speciali per non rovinare l'operazione.

Il sandwich di composito è realizzato sempre in ottica green: il core è realizzato tramite lastre di PET espanso, fornite da Diab, mentre per le fibre la squadra si è affidata al lino di Ecotechnilin, a cui si è rivolta anche per barche precedenti. Athena, questo il nome della barca che sta per uscire dal cantiere del DII, risulta essere una delle prime imbarcazioni completamente riciclabili prodotte in Europa.

Futuri studi, che potranno essere anche oggetto di tesi per i ragazzi del gruppo, non potranno prescindere dalla messa a punto di un processo di riciclo: grinding e termolisi sembrano essere, anche a detta di Arkema, le strade più promettenti, ma l'idea è quella di provare a ottenere la completa separazione delle fibre dalla matrice termoplastica anche attraverso processi chimici.

Achievements

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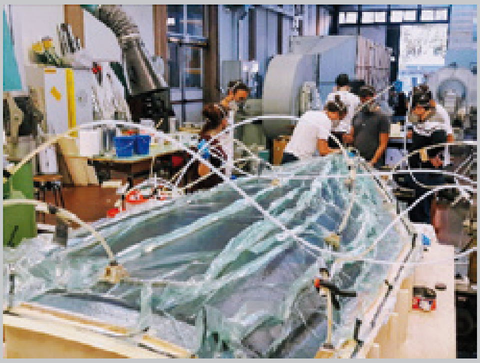


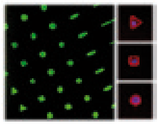
Main research topics:

- Compositi green
- Green economy

UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Cover story



L'immagine mostra dei micro pattern fluorescenti, aree bidimensionali di forma e dimensione controllata (da circa 100 a 1000 μ m²) realizzate su substrato vetroso. Essi sono ottenuti con una procedura foto-litografica complessa con cui si ottengono geometrie funzionalizzate con proteine (fluorescenti in figura) circondate da regioni non adesive ricoperte da catene lineari polimeriche che esercitano una repulsione entropica. In questo modo singole cellule (come le tre mostrate in figura) o monostrati cellulari aderiscono solo nelle zone adesive assumendone la forma e attivando precisi processi biologici.

Alessandro Gandin,
nato a Vittorio Veneto, il 30/08/1991. Dottorando in Scienza e ingegneria dei materiali e delle nanostrutture XXXIII ciclo. Consegue la laurea in Ingegneria dei materiali presso l'Università di Padova nel luglio 2017. Inizia successivamente il dottorato di ricerca nel gruppo HyMat della professoressa Giovanna Brusatin presso il DII. I suoi interessi di ricerca sono la sintesi e la caratterizzazione di biomateriali per lo studio dei meccanismi molecolari attivati dal mechanosensing cellulare. In modo particolare sullo studio e sulla sintesi di hydrogels sintetici e microstrutture.

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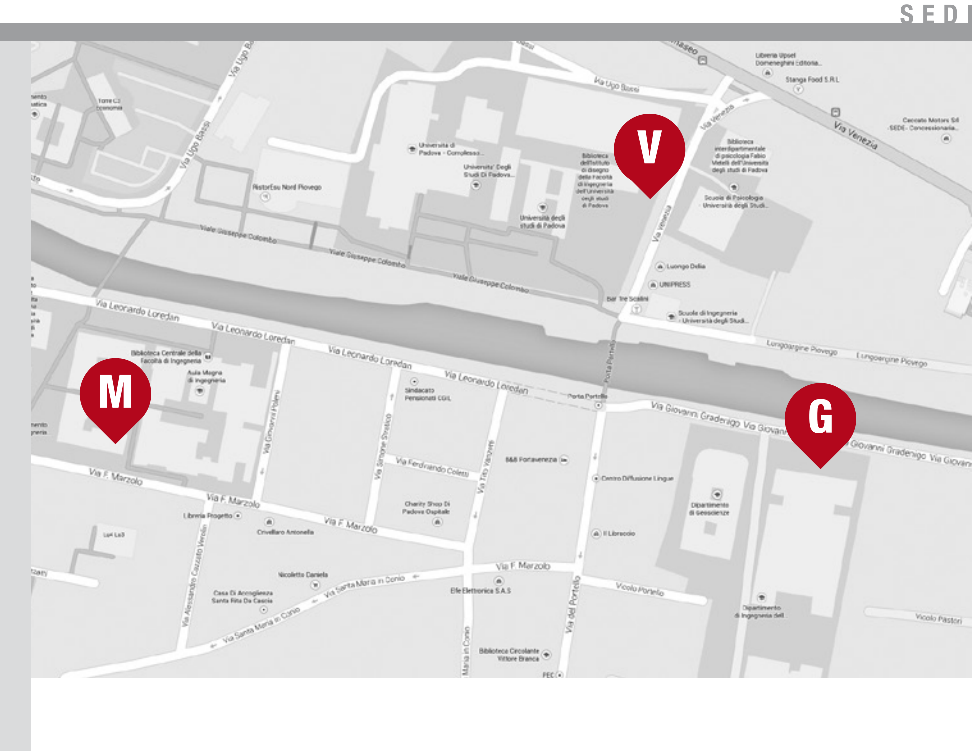

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