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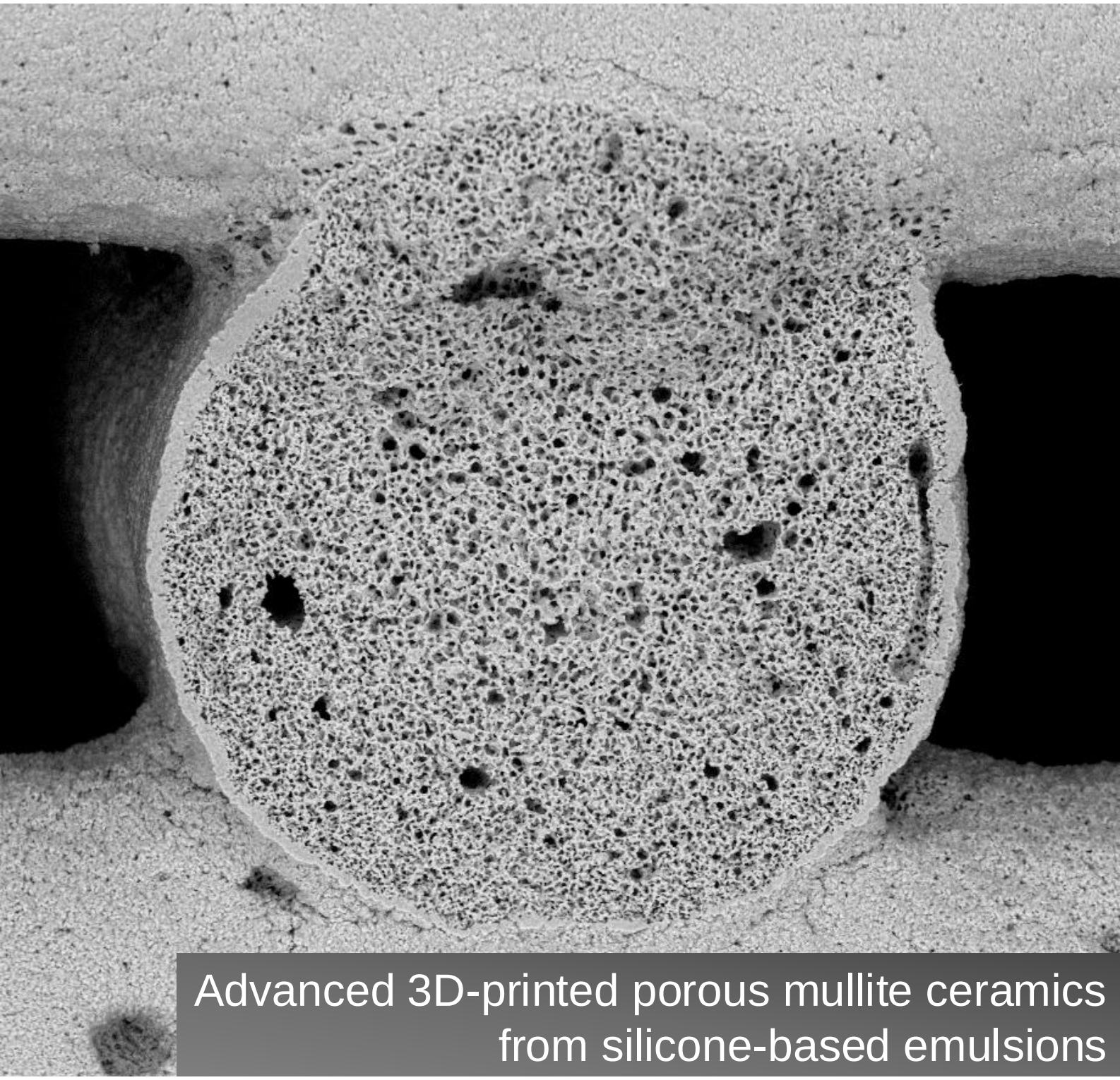
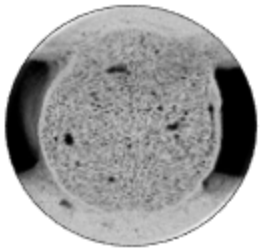
NEWSLETTER DEL DIPARTIMENTO DI INGEGNERIA INDUSTRIALE DELL'UNIVERSITÀ DEGLI STUDI DI PADOVA



Advanced 3D-printed porous mullite ceramics from silicone-based emulsions

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE
UNIVERSITÀ DEGLI STUDI DI PADOVA



COPERTINA

Advanced 3D-printed porous mullite ceramics from silicone-based emulsions

PAGINA

Il Club DII

Il Direttore Prof. Fabrizio Dughiero

Care colleghe, cari colleghi,
studentesse, studenti,
amici e personale tecnico amministrativo
del Dipartimento di Ingegneria Industriale,

con grande gioia vi presento il Club DII: l'iniziativa progettata e sviluppata dal nostro Dipartimento in collaborazione con UniSMART - Fondazione Università degli Studi di Padova e che include un programma di attività finalizzate a potenziare l'innovazione, la crescita professionale e le opportunità di networking tra studenti del Dipartimento di Ingegneria Industriale e le aziende.

L'obiettivo è promuovere una cultura imprenditoriale e innovativa, l'interdisciplinarità, nuovi modelli di apprendimento e strategie efficaci di employer branding creando un solido legame tra studenti di talento e imprese.

Il Club DII nasce infatti con la finalità di offrire agli studenti l'opportunità di partecipare ad attività esperienziali e formative che li renda i protagonisti del futuro mercato del lavoro; mentre garantisce alle aziende l'opportunità di employer branding di qualità.

I vantaggi per le aziende sono molteplici, tra cui: Recruiting, Employer Branding, Talent Development & Retention dei dipendenti coinvolti, Innovazione Tecnologica e Partenariati Strategici.

I vantaggi per gli studenti, invece, riguardano: Esperienza Pratica tramite la partecipazione attiva a progetti reali che migliorano le competenze professionali e aumentano l'occupabilità, Networking Professionale grazie all'opportunità di contatto con professionisti del settore e aziende, facilitando future opportunità di lavoro e Sviluppo delle Soft Skills.

Tra le iniziative proposte sono presenti: Hackathon HR, Innovation Contest, Acceleration Program, Summer School, Attività di amplificazione, Training, Networking Breakfast "Buon DII" e Newsletter.

L'evento di lancio è stato il 28 ottobre mentre il primo Hackaton HR si è tenuto il 26 e 27 novembre. Al contest hanno partecipato 35 persone tra studenti e rappresentanti aziendali. L'obiettivo era trovare soluzioni per promuovere l'innovazione organizzativa e favorire il dialogo intergenerazionale.

Il prossimo evento, il Networking Breakfast, si terrà il 18 dicembre. Vi aspetto numerosi.

Un saluto,

Fabrizio Dughiero

Materiali

Materials

DII research groups

cerAMglass

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This activity was carried out in collaboration with the Università degli Studi di Trento (Italy) and CNRS (France).

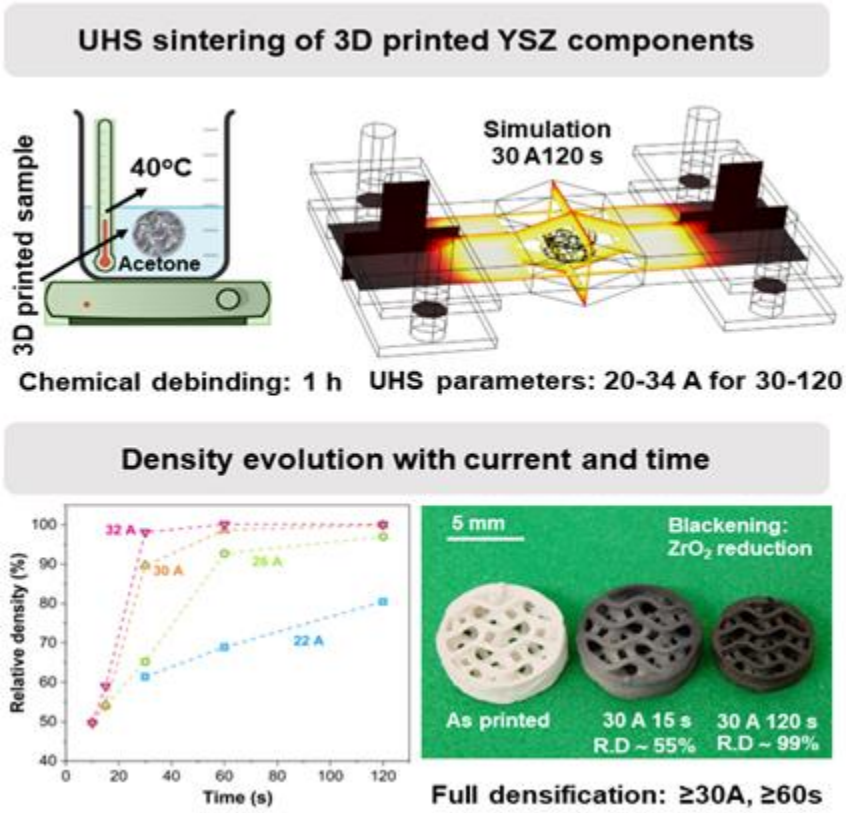
Main research topics:

- Additive Manufacturing
- Polymer Derived Ceramics
- Materials for the environment
- Biomaterials

Ultra-rapid debinding and sintering of additively manufactured ceramics by ultrafast high-temperature sintering

In the recent years, field-assisted sintering techniques have gained popularity as a way to reduce the processing time and energy. However, most of the research study has focused on the field-assisted sintering of uniaxially or isostatically pressed powder compacts with simple shapes. Additive manufacturing (AM) allows fabricating complex geometries with fewer constraints compared to the conventional fabrication techniques. Most techniques involve the use of ceramic powders embedded in an organic binder, which is typically removed through a slow thermal debinding process, representing the bottleneck of the process.

Herein, we prove for the first time that ultra-rapid debinding and sintering are possible for complex 3 mol% yttria-stabilized zirconia (3YSZ) components produced using fused filament fabrication (FFF). The printed components were first chemically debinded in acetone thus removing about one-half of the binder, and then thermally debinded and sintered by ultrafast high-temperature sintering (UHS) in a single-step process (30 to 120 s). With optimized parameters, fully dense components were obtained with tailored microstructure (see Figure) and nanometric grain size. The sintered artefacts were crack-free even at the microscopic level. This work provides a first proof of concept for ultra-rapid processing (debinding and sintering) of additively manufactured ceramics, thereby reducing the overall processing time by 99%. This approach paves the way for rapid processing (debinding and sintering) of additively manufactured ceramics with reduced energy consumption and carbon footprint.



MotoStudent: QuartoDiLitro again among the top teams!

The QuartoDiLitro-Petrol and QuartoDiLitro-Electric teams confirmed their place among the top teams in the international student competition MotoStudent. At the final event, which took place at the Motorland Circuit of Aragon in Spain, the Padova teams took fourth place overall (Electric) and fifth place overall (Petrol). The Electric team also won the 'Best Rookie' award.

The aim of the competition is to design, build and test a prototype racing motorbike. Students from Padova have been participating in the competition since 2015 with an internal combustion vehicle and from 2022 also with an electric vehicle. The vehicles developed are assessed from an engineering point of view (e.g. design choices), from a static point of view (e.g. structural strength) and from a dynamic point of view (e.g. acceleration, braking, top speed, lap time, etc.) by a committee composed of technicians from the industry.

Participating in the project, which is based in the Department of Industrial Engineering and recognised by the University through the Open Badge, are students from various departments of the University of Padova. Twenty-four students took part in the trip to Spain (Marco Adami, Gabriele Bello, Riccardo Benvegnù, Giulio Bojan, Alessandro Carraro, Alessandro Chillon, Federico Dal Molin, Giorgio Daví, Lorenzo De Paoli, Alex El Shorbagi, Nicola Graziato, Mattia Gulisano, Andrea Malachin, Edoardo Marangoni, Damiano Mariuzzo, Filippo Padrin, Tommaso Reschiglian, Gianmarco Rocco, Nicolò Romanato, Kevin Sasso, Andrea Serafin, Sebastiano Volpato, Eugenio Zanta, Stefano Zanotto), led by two team leaders (Alessandro Maiorana - Petrol team) and Giuseppe De Tuglie (Electric team), under the supervision of the Academic Tutor (Prof. Matteo Massaro).

Sistemi meccanici

Mechanical systems

DII research group

MMSA (Mechanism and Machine Science and Applications)

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Main research topics:

- Industrial and service robotics
- Mechanical drivers and control
- Mechanical vibrations
- Mechanisms and automated machines
- Road vehicles
- Robotic systems for human interaction

Sicurezza ambientale e industriale

Environmental and industrial safety

DII research groups

SAM.lab

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This study was carried out within the MICS (Made in Italy – Circular and Sustainable) Extended Partnership and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.3 – D.D. 1551.11-10-2022, PE00000004).

Main research topics:

- Sustainability assessment and management
- Industrial process safety and risk analysis
- Eco-innovation and circular economy

Health&Safety in European documents on Circularity and Sustainability

To overcome the problem of global scarcity of natural resources at a time of rapid climate change and increasing demand of energy and resources, a series of policies and initiatives on sustainability to ensure sustainable consumption and growth has been introduced by European Union. One of the principal instruments introduced by EU is the Circular Economy (CE). Circular Economy introduces changes in industrial processes and this is one of the risks that in the world of work must be assessed in company risk management. As part of the LCA Group within the MICS (Made in Italy - Circular and Sustainable) Extended Partnership, we wondered to understand how much these changes are taken into account in European legislation, especially in occupational health-safety.

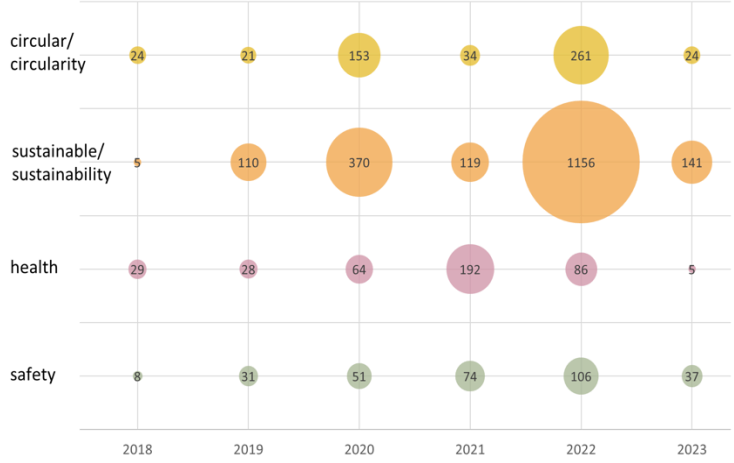
A systematic literature review was performed observing the official website of European Commission and in EUR-Lex site with the research question: "How much do European documents on circularity and sustainability deal with occupational health and safety?".

From this review it emerged that European legislation on sustainability and the circular economy has been issuing several directives, regulations and communications, especially in recent years. However, focusing the attention to "health" and "safety", these topics are significantly less present than "circularity" and "sustainability" topics (see Figure).

To conclude, the circular economy introduces changes that lead to new risks for workers, but within the European legislation of circular economy and sustainability little attention is paid on the occupational health and safety which is essential for the success towards a more sustainable future.

This research explored the connection between sustainability, circularity and occupational health and safety in the European legislations. The idea is deepen this research but also to broaden the search to the scientific literature and thus investigate the opinion of the scientific community with regard to the connection of these three topics.

Other details about the research was presented in EURECA-PRO conference in Chania in September 2023 (https://conference.eurecapro.eu).



Frequency of words 'circularity', 'sustainability', 'health', 'safety' in European publications in the last 6 years (the diameter of bubbles represents the numerosity of documents related to the topic)

High temperature thermal energy storage with direct electric charging and convective discharging

High-temperature thermal energy storage (TES) is considered one of the most promising technologies for grid-scale electricity storage.

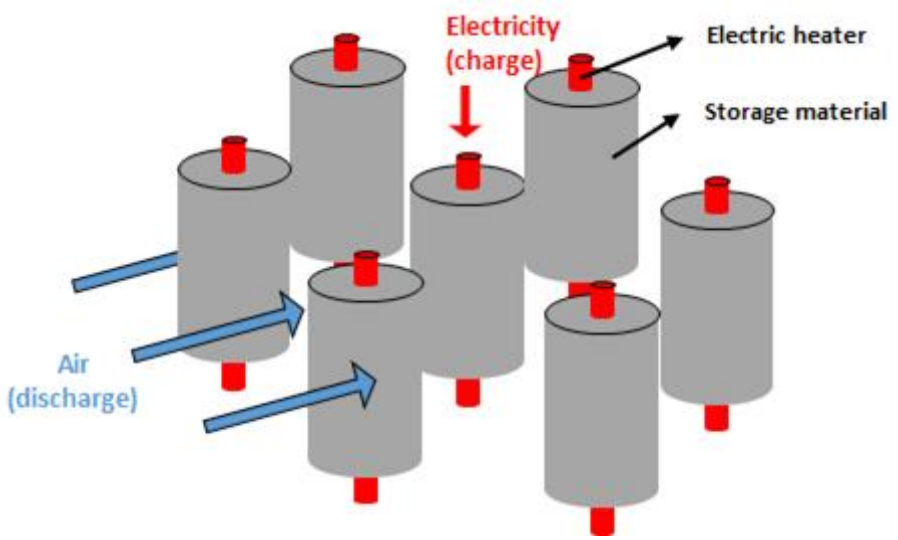
In a conventional TES system, both the charge and discharge processes are carried out by convective heat exchange between the storage material and a heat transfer fluid. This involve transportation losses, low flexibility and, in some cases, low efficiency. Therefore, to overcome this issues, an innovative modular TES configuration has been proposed as shown in Figure.

The innovative concept consists of a set of electric heaters, surrounded by a matrix of ceramic material. During the charge, the storage material is heated up by the electric heaters, which exploit high-voltage electrical power. During the discharge phase, the heat transfer fluid absorbs the heat from the storage material and then delivers it to the power cycle. In this manner, the charge efficiency is boost and the round-trip efficiency improved. This innovative design can be stand-alone as well as installed in any kind of thermomechanical energy storage system like compressed air energy storage or pumped heat energy storage.

The geometry of the single storage element was optimized comparing different cross-section shapes.

Results show that the elliptical cross section provides the best performance in terms of pressure drops reduction. Moreover, with the elliptical cross section the heat exchange between air and solid material is two times more efficient compared to circular and hexagonal elements.

The design of the overall TES, in terms of placement of the storage elements was also investigated. An inlet air velocity of 0.3 m s^{-1} and a void fraction of 0.4 were identified as providing the best trade-off between pressure drops and heat exchange.



Design of the TES charged with electric heaters and discharged with a heat transfer fluid.

Energia

Energy

DII research group

Turbomachinery and Energy Systems

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This study was carried out in collaboration with the Power and Control Systems Research Laboratory of the University of Warwick (UK).
The study was part of an EPSRC project.

Main research topics:

- Energy storage systems
- Fundamental cavitation research and development of numerical tools
- Power Plant Dynamic Modelling and Live Cycle Assessment

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering, biotechnology and health technologies

DII research groups

Biomechanics - Mechanics of Biological Materials

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The research activity is in collaboration with the Department of Surgery, Oncology and Gastroenterology, UNIPD. Funded by University of Padova, Project n. BIRD235152, "ERRA".

Main research topics:

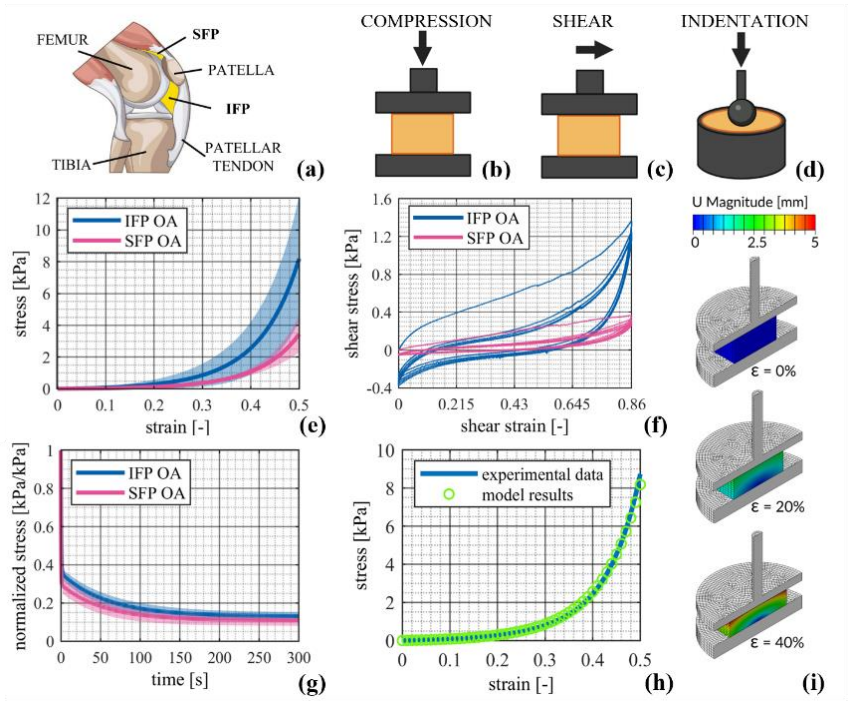
- Mechanical behaviour of biological tissues
- Constitutive modeling of biological tissues
- Computational biomechanics
- Interaction phenomena between human body and medical devices
- «In silico» techniques for the 3R approach to product design

Influence of knee osteoarthritis on the mechanical behaviour of knee fat pads

Osteoarthritis (OA) is the most common musculoskeletal disorder worldwide which preferentially affects knee joints, leading to pain and disability. The role of knee fat pad tissues, i.e. infrapatellar fat pad (IFP) and suprapatellar fat pad (SFP), pertains to distributing and damping mechanical actions during articular activity. Still, both are also potential sources of adipokines and cytokines which contribute to OA progression.

Experimental tests were performed on IFP and SFP samples collected from a total of 20 patients (M: 7, F:13; age 72 ± 9 years; BMI 29 ± 4 kg/m2) affected by OA undergoing Total Knee Arthroplasty (TKA) at the University-Hospital of Padova (CESC Code: AOP2649). For compression tests, loading-unloading (40% strain at 10-100-1000 %/s strain rates) and stress relaxation (6 ramps of 10% strain; 100%/s strain rate; 300s of resting) protocols were carried out. Concerning the shear tests a loading-unloading procedure was adopted (40° shear strain angle at 10-100%/s strain rate), while for the indentation tests, a stress relaxation procedure was performed (5 ramps of 15% strain; 3000%/s strain rate; 300s of resting time).

Experimental results showed that OA IFP stiffness was higher that of the OA SFP for all mechanical tests while the viscoelastic properties were similar. These outcomes led to defining an almost incompressible, isotropic, visco-hyperelastic model to describe the tissue properties. These outcomes provided the basis for developing computational tools that will allow the investigation of the influence of OA on knee mechanics. These new insights may be useful during surgical intervention procedures, e.g., in the assessment of the possible removal of IFP in the case of TKA.



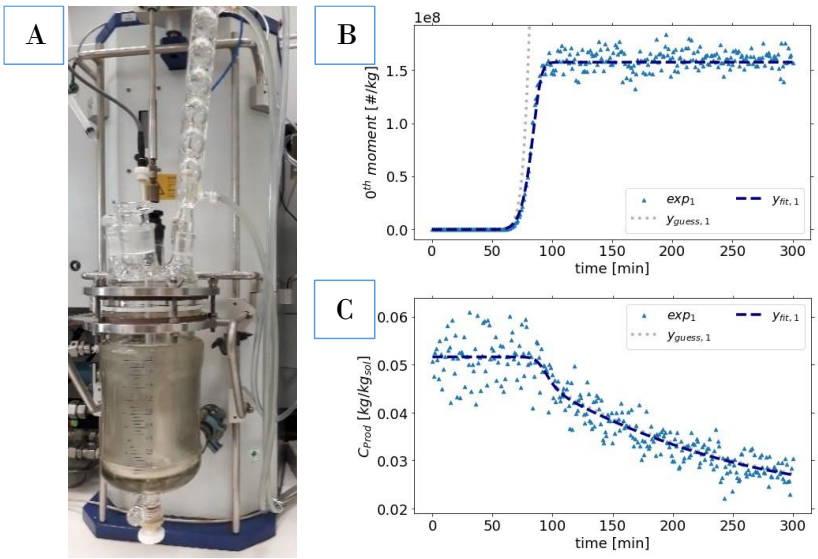
FP and SFP localization(a). Compression (b), shear (c), and indentation (d) test setup. Equilibrium stress-strain (e), shear stress-shear strain (f) and normalized stress-time curves (g). Computational simulation of compression tests: experimental vs model results (h) with displacement contours (i).

Model-based approaches to accelerate the development and scale-up of pharmaceutical processes

In the recent past, pharmaceutical companies have been facing a series of arising challenges, which involve an increasing demand in research efficiency, production capability and quality assurance. Their interest is in reducing time and money required to bring drugs to the market, with clear benefits also for patients, while guaranteeing that strict product specifications are satisfied, in order to minimize risks and wastes.

Models can play a key role in this context, since they can provide quantitative descriptions of the process unit operations and can be used to simulate their behavior and optimize performance. In particular, first-principles models take advantage of the knowledge of the physics of the system, and can be used to accelerate the set up of the manufacturing process by providing tools to develop the process at small-scale and then to predict the process performance at manufacturing scale. In this respect, a key challenge is related to the transfer of information from the lab to the industrial plant, and to a rapid calibration of the model for representing the larger scale in a reliable way. Model-based design of experiment techniques can be used to optimize the generation of experimental data, which in an industrial plant are typically scarcer and more costly to obtain, thus decreasing both money and time expenditures.

The project focuses on the definition of a model-based workflow to target the scale-up and optimization of crystallization unit operations, which are at the core of many Active Pharmaceutical Ingredients (APIs) production processes. The goal is to provide a modelling framework to represent the nucleation and growth of crystals in an industrial environment, and to define an effective procedure to tune up the model using available instrumentation and sensors, in order to propose optimal operation parameters in product manufacturing at large scale.



Laboratory scale crystallizer (A). Plots of in-silico generated experimental points and corresponding fitting curve (dashed line) for two model outputs: number of formed crystals over time (B) and concentration of API (C).

Processi e prodotti industriali

Industrial processes and products

DII research group

CAPE-Lab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This project is carried out in collaboration with F.I.S. - Fabbrica Italiana Sintetici (Montecchio Maggiore, Vicenza, Italy).
Fundings: F.I.S. and Ministero dell'Università e della Ricerca (MUR) via PNRR, Missione 4, componente 2 "Dalla Ricerca all'Impresa" – Investimento 3.3.

Main research topics:

- Data analytics and process digitalization
- Model development and identification
- Low carbon systems and technologies
- Product design and quality control

Materiali

Materials

DII research groups

CERAMGLASS

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https://research.dii.unipd.it/ceramglass

This contribution is part of the dissemination activities of 'GLASS_Trea.S.U.Res' (PRIN 2022 PNRR project).

Main research topics:

- Nano-structured ceramic composites from preceramic polymers and fillers
- Advanced porous ceramic components
- Bioceramics from innovative formulations and processes
- Monolithic and cellular glass and glass-ceramics.
- Innovative building materials from inorganic waste
- Additive manufacturing of porous and dense ceramic components

Upcycling of un-recyclable opal glass waste through alkali activation

Opal glass is widely used in the production of tableware for its high mechanical strength, hygiene and aesthetic properties, due to the presence of fluorides that give it the typical white colour. The presence of fluorides in its composition prevents the recycling of waste opal glass that is normally landfilled. Discarded opal glass can be eligible to produce sustainable alkali-activated materials (AAM) reducing consumption of raw materials and CO2 emissions. The alkaline attack determines the gelation of glass suspensions, according to hydration of glass surfaces, followed by condensation starting from 40°C ('cold consolidation'). Alkali are mostly expelled from the gel, according to the formation of water-soluble hydrated carbonates.

Opal glass fine powder (< 75 μm) is stirred for 3h at 500rpm into mild alkali activation (2.5M) and hardened at 40°C for 7 days. The obtained samples withstand boiling tests and show a compressive strength of 30.3 MPa. The resistance achieved by activated opal glass is comparable to that of other building materials such as concrete but the density is considerably lower. The molecular mechanism behind this behaviour is still under study and will be clarified by NMR analysis.

Opal glass can also be used as a matrix with coarse flakes of LCD glass added as an inert phase, obtaining a solid material with excellent aesthetic characteristics. In addition, recent evidence proves that microwaves treatment allows to greatly simplify the curing process of samples after activation saving time and energy and increasing the final material strength.

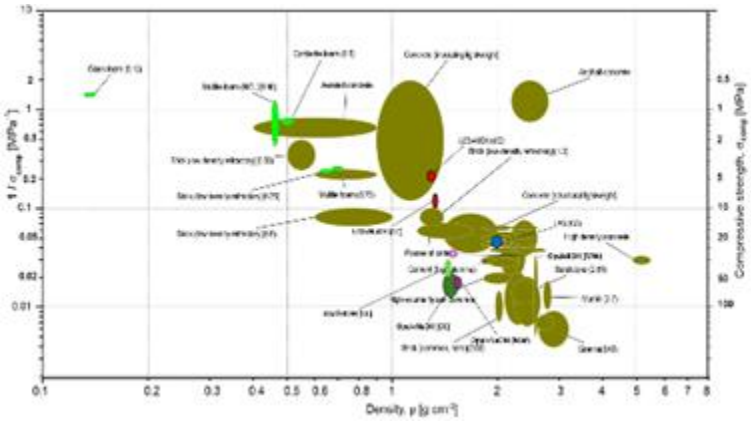

Figure 1: *Compressive strength/density trade-off of CC and MW activated Opal glass products (computed by means of CES software package).*

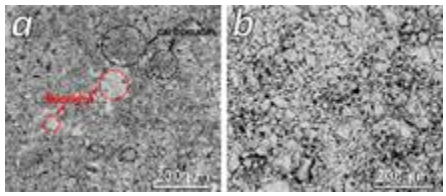

Figure 2: *SEM images of activated Opal glass before (a) and after (b) boiling test (1h in distilled water).*

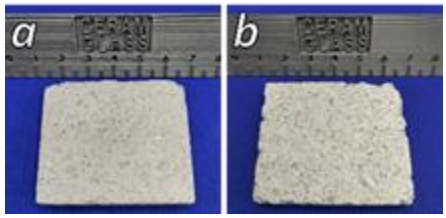

Figure 3: *Opal glass composites: Opal with LCD (a) and BASG (b) coarse flakes.*

Barrier membranes engineering for Guided Bone Regeneration

According to WHO data, over 3.5 billion people suffer from oral cavity issues. In cases of edentulism, immediate intervention through dental implants or bone grafts is crucial to limit alveolar bone resorption. Guided Bone Regeneration (GBR) uses barrier membranes to isolate the defect site and prevent unwanted cells from interfering with bone regeneration. This technique promotes alveolar bone regeneration, overcoming the challenge of implanting screws where insufficient bone tissue exists and reduces stress-induced necrosis caused by screw insertion and enhances bone tissue vitality. Membranes also prevent soft tissue colonization on bone grafts (Figure 1).

OsseoGuard® membranes, made of type I collagen crosslinked with formaldehyde, are commonly used in GBR. Our research aims to enhance their bioactivity for better bone regeneration. We functionalized these membranes with chitosan (CS), a natural, biocompatible, and antibacterial polysaccharide that promotes coagulation, hemostasis, and osteoblast activity and provides strong antibacterial properties. functionalized with the peptide GBMP1α (sequence 48-69 of BMP-2), that promotes calcium deposition, osteoblast adhesion, and the expression of essential genes for bone regeneration.

We used two different linkers (EDC/sulfo-NHS and BDDGE) to covalently anchor the engineered CS to the membranes (Figure 2). Both approaches led to significantly increased osteoblast proliferation, mineralization, gene expression, and antibacterial activity compared to commercial membranes (Figure 3), without altering mechanical properties. Current efforts are focused on completing in vivo tests. The next steps include functionalizing non-crosslinked membranes and exploring direct functionalization with GBMP1α and its analogues for further improvements.

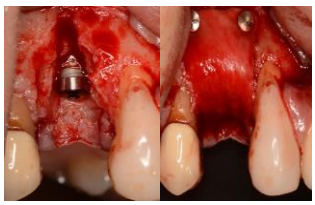

Figure 1: *Barrier membrane on a defect site.*

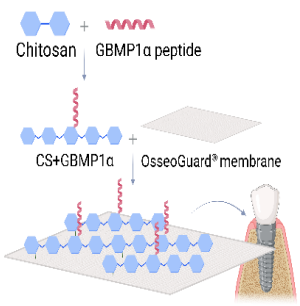

Figure 2: *Functionalization scheme.*

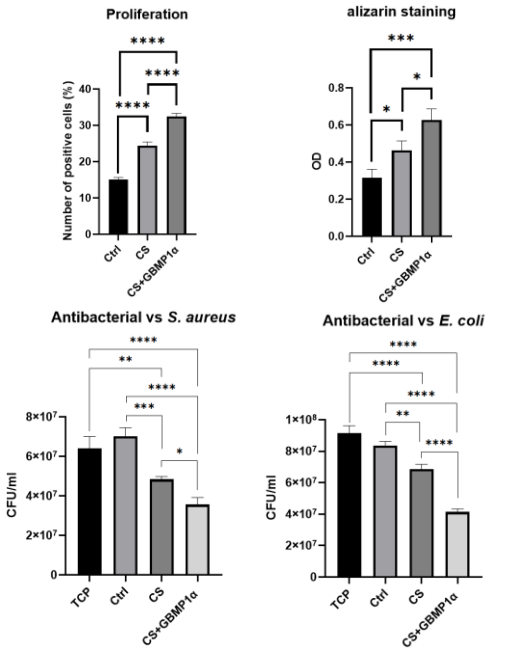

Figure 3: *Biological assays on membranes functionalized via EDC/sulfo-NHS, yielding the best results.*

Bioingegneria, biotecnologia e tecnologie per la salute

Bioengineering, biotechnology and health technologies

DII research group

Chemical Bioengineering

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The research project is carried out in collaboration with the Dental Clinic of the University of Padova, prof. Andrea Bagno (DII-UNIPD) and prof. Paola Brun (DMM-UNIPD).

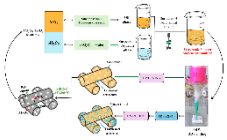
Main research topics:

- Peptide synthesis, purification and characterization
- Investigation of structure-activity relationship in biopolymers
- Biomaterials functionalized with bioactive peptides
- Scaffold of self-aggregating peptides decorated with adhesive, growth or angiogenic sequences
- Matrices for tumor tissues models
- Quorum sensing in the design of antibacterial surfaces
- Functionalization of decellularized tissues

UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Cover story



Lo studio presenta un approccio innovativo per la fabbricazione di strutture reticolari di mullite altamente porose tramite stampa 3D Direct Ink Writing di emulsioni a base di silicone.

Il sistema di sospensione-emulsione, in cui una sospensione acquosa di nano-allumina è emulsificata all'interno di una fase oleosa di silicone/acrilati, incrementa significativamente la reattività della miscela silicone-allumina finale, consentendo una completa mullitizzazione a una ridotta temperatura di sinterizzazione di 1300°C.

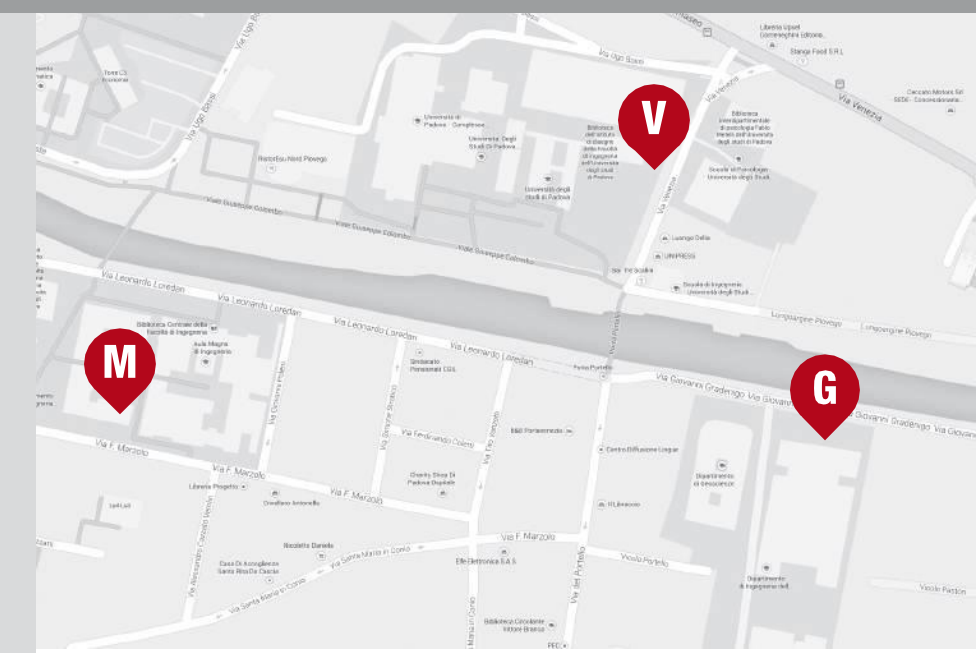
Inoltre, la combinazione di una consolidazione tramite UV e di un approccio di congelamento dell'acqua nella miscela permette di ottenere strutture reticolari in mullite con una porosità gerarchica notevole (~80% di porosità aperta) e proprietà meccaniche adeguate ad applicazioni come filtri o supporti per catalizzatori.

Valentina Diamanti

Laureata in Bioingegneria presso l'Università degli Studi di Padova, è attualmente Dottoranda in Industrial Engineering, curriculum Materials Engineering, sotto la supervisione del Prof. Enrico Bernardo e del Prof. Hamada Elsayed.

Il progetto di ricerca, iniziato nel 2023, si incentra sulla manifattura additiva di ceramiche avanzate, supportata dall'impiego di emulsioni innovative a base siliconica, con particolare interesse per i materiali ceramici impiegati nel settore biomedicale.

SEDI



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