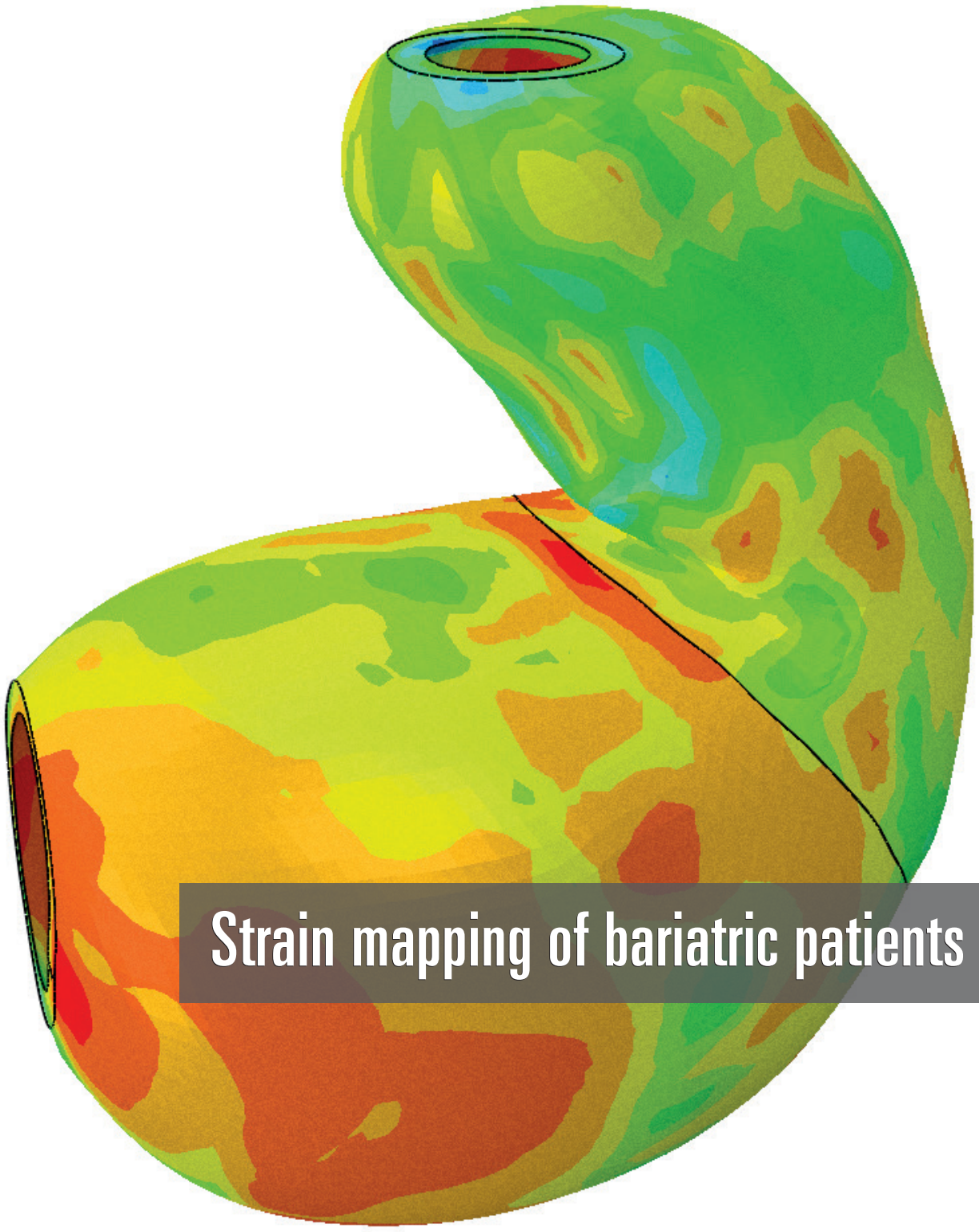
DII INFORMA 02.8
SETTEMBRE 2022

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



# Strain mapping of bariatric patients

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

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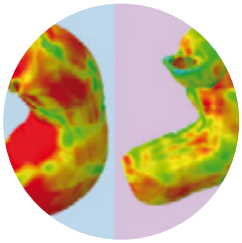

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DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

# Electrically enhanced plasticity of duplex stainless steel UNS S32750

Electroplastic Effect (EPE) is the influence of electrical current on the microstructure and the plastic flow of materials. In this work, duplex stainless steel UNS S32750 has undergone uniaxial tensile tests with the aid of pulsed electrical current. Different current densities and thermal tests were conducted to separate the EPE from the heating effect. Approximately a linear increase of material temperature, reaching a maximum of 370 °C for the highest current density was observed. Segmentations of tensile test curves are due to the electrical pulses (Fig. 1a). A gradual decrease in UTS increasing current density and thermal regime is clear due to the softening effect of the temperature. It is interesting to observe the approximately constant fracture strain (FS) increasing the thermal regime as opposed to the continuous current case. For each current regime, stress jumps of the same current frequency can be observed. A clear correlation between current density and the stress reduction has not been observed. A dynamic annealing could have taken place during the electrical pulses, which reduced the dislocation density, increasing the plastic strain. Pulsed electrical tensile tests (Fig. 2) show an increase in uniform elongation much more evident compared to the thermal and the continuous current tests. All relative elongations are comparable except for the test conducted at the highest current density because of the high temperature. The increase in uniform elongation compared to the thermal counterpart is more than 30%, moreover it remains constant for all the current densities. FS is constant and comparable with that of the baseline despite the increase in the test temperature, conversely to the continuous current tests. Relative uniform elongation of pulsed current tensile tests were significantly higher compared to continuous current (approximately 30% more, compared to the baseline) while UTS and yield stress were not affected. FS was constant and comparable to that of the baseline despite the material increase in temperature. Stress jumps of few MPa were observed after each current pulse that could be explained as a dynamic annealing due to the increased dislocations mobility and annihilation probability. An uneven distribution of current density due to the presence of the ferrite matrix is the possible explanation as the occurrence of the electroplastic effect in a material presenting two different phases with opposite behavior with respect the electrical current.

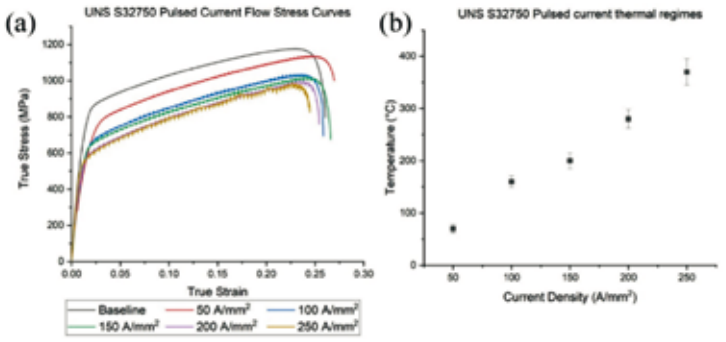


**Fig. 1** Flow stress curves of UNS S32750 under different pulsed current densities (a), temperature reached by the steel at different current densities (b)

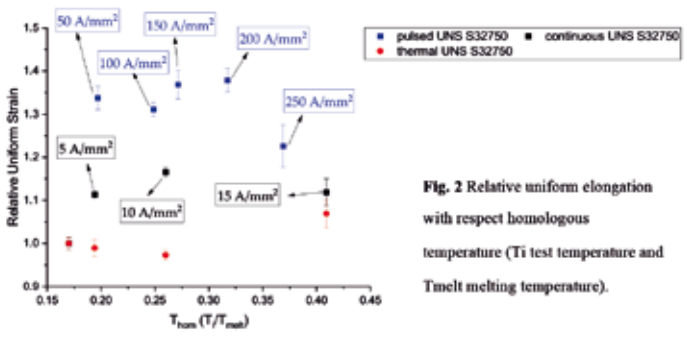


**Fig. 2** Relative uniform elongation with respect homologous temperature (Ti test temperature and Tmelt melting temperature).

Materiali

*Materials*

DII research group

Metallurgia e Ingegneria Elettrica


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The research activity is carried out in collaboration with:

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Main research topics:

- Electroplastic effect
- Metallurgy
- TRIP assisted steel
- Coatings
- Corrosion protection

Energia

*Energy*

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Progetto BIRD2021: maximaLED: fine tuned LED technology to boost biological light exploitation in Arthrospira maxima

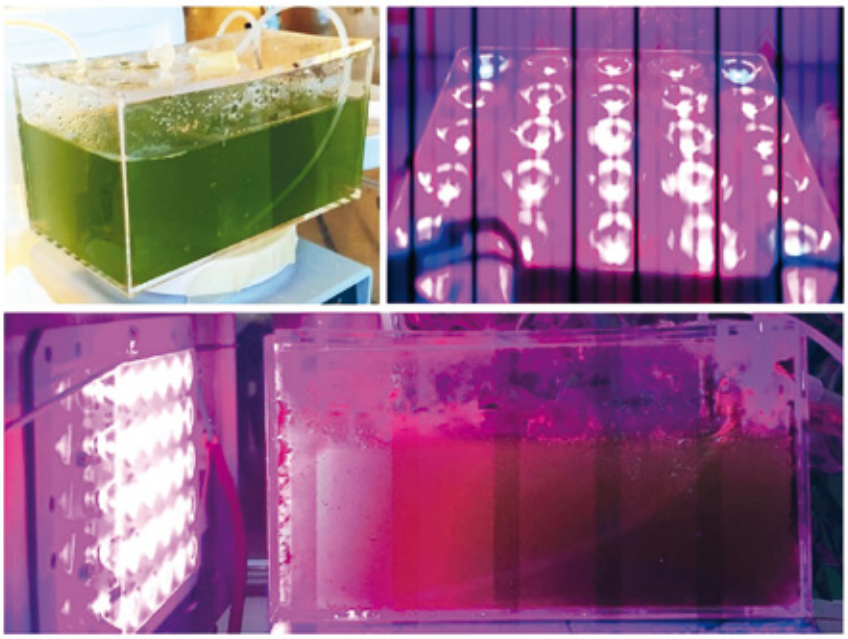
# A multidisciplinary approach to improve microalgal productivity and energetic conversion

Interest in the production of algae-based products and microalgal biomass has exponentially increased in the last decade. Microalgae production is crucial since they constitute potential sources for: i) human nutrition, ii) biofuel, iii) aquaculture products for other organisms, iv) raw substances for pharmaceuticals and cosmetics, and v) biofertilizers.

Autotrophic microalgal growth requires a light source, which can be provided either by sunlight, or artificially with lamps. Although sunlight is the cheapest choice, it is characterized by a variable biomass production, in terms of both quantity and composition. Delivering light by artificial illumination has been proposed as an effective way to overcome these problems. However, the energetic cost is relevant, and the efficiency of artificial light needs to be substantially improved to allow market penetration. At this moment, the overall energy efficiency of a continuous microalgae cultivation system, integrated with artificial light, has not been assessed yet.

A multi-disciplinary approach, represented by different research groups of the Department, is needed to carry out a deeper energy efficiency assessment and modeling of a next generation LED-based continuous photobioreactor.

In order to study the effects of light quality on microalgal performances, the cyanobacterium Arthrospira maxima was cultivated under a custom designed R/B (red/blue) LED lamp at increasing light intensities. A mathematical model was then implemented to examine the effects of process variables on microalgal growth, and to predict maximum biomass productivity in the multi-wavelength spectrum employed, which was also included in the simulation tool. Both the photosynthetic and LEDs efficiencies were examined for energy evaluation. It was found that integrating tailored LEDs in microalgal cultivation increases process efficiency by reducing light energy waste. Moreover, integrating tailored LEDs was also found to be more efficient than using white LED source, due to their higher energy efficiency: considering efficiency of the R/B LED lamp, there was a clear-cut gain in the energy efficiency of the process. This may be interesting in view of expanding the use of artificial illumination in microalgae cultivation, allowing the design of highly efficient production processes.



Main research topics:

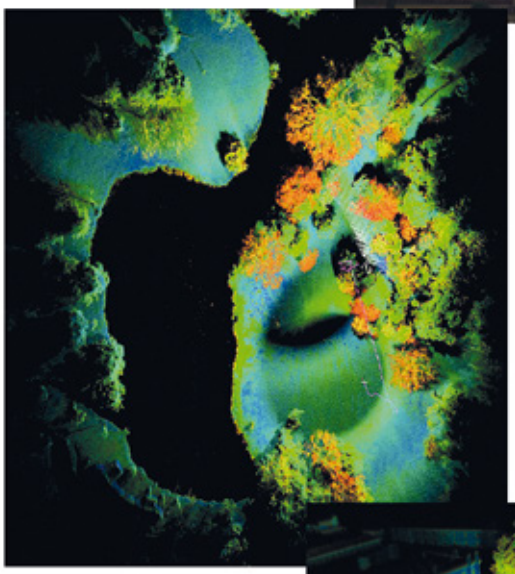
- Microalgae cultivation for industrial and environmental applications
- Advanced lighting sources for industrial applications

# Use of LIDAR on UAVs for spatial analysis and monitoring environmental parameters at Villa Bolasco garden

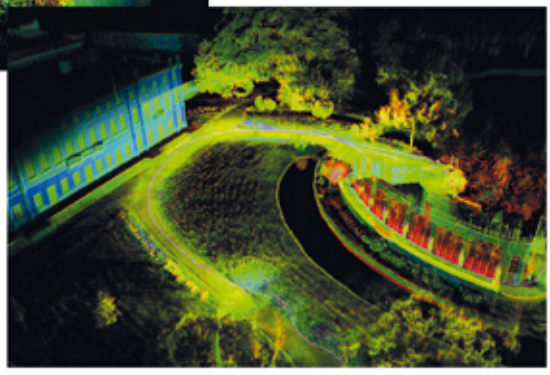
A joint team of researchers from Department of Industrial Engineering (DII) and Center of Studies and Activities for Space "CISAS" G. Colombo designed and integrated an autonomous remote monitoring system (including LIDAR and infrared cameras) on a commercial UAV for remote monitoring of extended areas. Tests very conducted in the Villa Parco Bolasco complex in close collaboration with the Interdepartmental Research Center of Geomatics (CIRGEO) the and Department of Land, Environment, Agriculture and Forestry (TESAF), which coordinate research activities related to complex, owned by the University of Padua.

The collaboration between the different souls of the University makes it possible to treasure the knowledge of different departments and centers by providing an integrated approach to monitoring the ecosystem and the environment.

Point clouds reconstructed from pulsed laser data are used for spatial analysis of the complex and elaboration of environmental variables especially regarding tree height and diameter calculation.



LIDAR reconstructed point cloud of the trees and lake of Villa Bolasco park



LIDAR reconstructed point cloud of the Villa and surrounding buildings

Sistemi aerospaziali

*Aerospace Systems*

**DII research group**
Flight dynamics and space systems
Measurement and Technologies for Space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Sebastiano Chiodini
Alessio Aboudan
Mirco Bartolomei
Lorenzo Olivieri

Center of Studies and Activities for Space "CISAS" G. Colombo

Main research topics:

- Dynamics of atmospheric flight and UAV
- Dynamic analysis of flight systems
- Measurements, instrumentation and technologies for aerospace applications

Sistemi Elettrici

*Electrical Systems*

DII research group

MEMOS

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This research was carried out in collaboration with:
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Ing. Simone Falco from the University of Oxford
Prof. Yinsheng Li and Prof. Zhengren Huang from the Chinese Academy of Sciences

Main research topics:

- Multiphysics modelling
- Coputational Electromagnetics
- Optimization
- Simulation

# Multiphysics modelling of flash sintering of ceramics

Flash sintering (FS) is a new type of electric field assisted sintering method where ceramics can be sintered in just a few seconds by the application of a sufficiently high electric field to a pre-heated powder compact. The flow of current through the sample leads to Joule heating, and the negative temperature coefficient of resistivity in the green body induces fast power dissipation and thermal runaway. Compared with conventional sintering, FS has three major significant advantages: lower furnace temperature, faster heating rate, and shorter sintering time. These characteristics enable FS to be an energy-saving technique and suitable for preparing fine-grain ceramics. Although FS has attracted worldwide attention in ceramics research, it has not been applied to the industrial manufacturing level yet. The key problem of FS is the easy generation of thermal gradients, which are closely related to the formation of preferential current paths inside the ceramic sample. Since the sample surface releases heat via thermal radiation during FS the sample surface is much colder than the core region. The hotter region is generally more conductive, resulting in increases of local current density and power dissipation. Consequently, the sample centre becomes much hotter and more conductive, thereby causing local overheating and even the appearance of localised hot paths. A significant thermal gradient is formed between the core and the surface, which is detrimental to the integrated densification and microstructure homogeneity of ceramics. In this study, a new uniform FS method is developed, to improve the homogeneity of 3YSZ by current path management. The preferential current path during FS is intentionally shifted from core to near-surface by judicious design of sample geometry and electrode configuration. The concentrated Joule heating near the sample surface can effectively balance the superficial heat loss by radiation, creating a more uniform distribution of temperature inside the sample. The combined effect of shape, aspect ratio and multiple electrodes led the specimen to reach an high relative density of 99.7 % and a flexural strength of 1501 ± 15 MPa, and with the uniform grain size distribution.

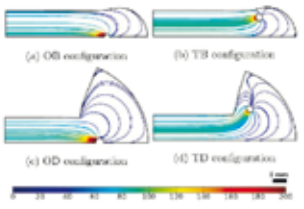


*Fig.1 - Current density streamline (in mA/mm²) in four 3YSZ samples at the end of FS analysed by the numerical model.*

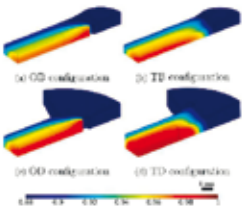


*Fig.2 - Temperature distribution (in K) in four 3YSZ samples at the end of FS analysed by the numerical model.*

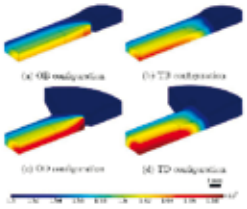


*Fig.3 - Relative density distribution in four 3YSZ samples at the end of FS analysed by the numerical model.*


*Fig.4 - Snapshots of the specimen at 2 s before, at the beginning and at the end of flash event.*

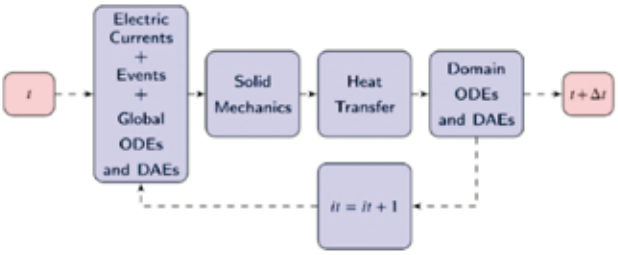


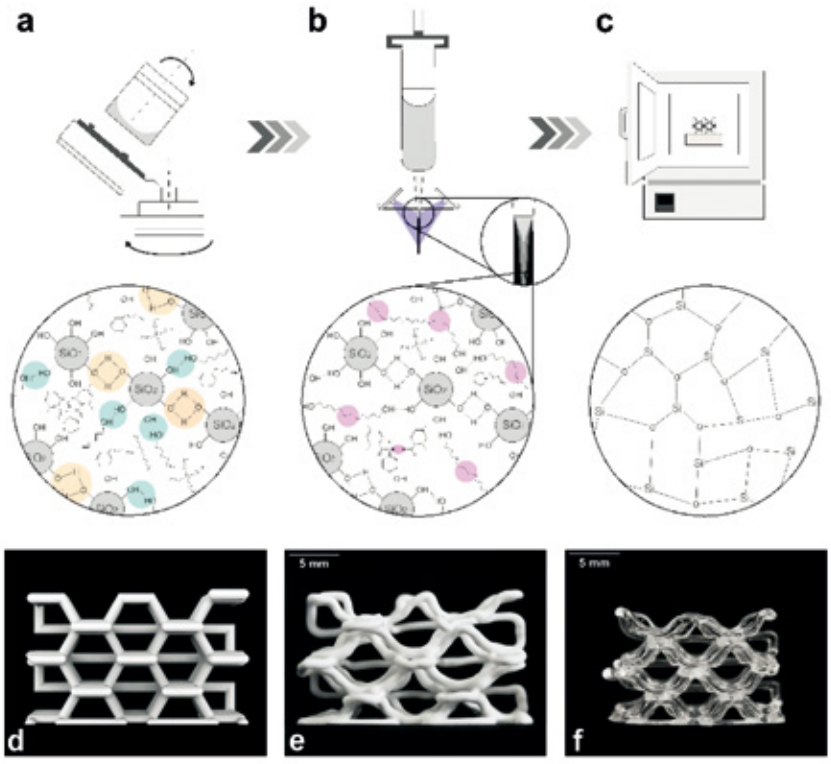

*Fig.5 - Segregated solver scheme: the physical processes are solved in four internal steps, which are repeated until the global tolerance is under $1e^{-6}$.*

# Hybrid additive manufacturing for the fabrication of freeform transparent silica glass components

Additive manufacturing (AM) techniques for the fabrication of ceramic and glass components have been developed extensively over the past years. Each technology has been proven to be best suited for specific feedstock, dimensional scales and component designs; indeed, each of them possesses specific requirements for a successful printing process, limiting its wider applicability. The combination of multiple processes can exploit their benefits and overcome their limitations. Specifically, the hybrid extrusion-photopolymerization setup developed by our group allows for the spatial UV-assisted direct ink writing of freeform silica glass components from a photocurable colloidal solution, with little rheological constraints and no influence of scattering and absorption.

We directed the rheological behavior and the reactivity of the silica containing ink by tailoring the particle-liquid interactions as well as with the addition of a silicon alkoxide; the latter also contributes to the final silica yield, allowing for fast thermal treatments despite the low particle loading of the ink.

We designed and fabricated a 3D honeycomb-like structure with overhangs and self-supporting features as a proof-of-concept for the capabilities of the hybrid setup; its sintering results in a highly transparent component, thanks to its continuous, homogeneous struts with no stair-step effect. High transmittance, density, hardness and refractive index are all indicative of a dense silica glass. The 3D honeycomb-like structure is much lighter compared to conventional, 2D, extruded ones, and could be exploited as scaffolding or metrology frames in applications requiring lightweight, low CTE transparent components. We are currently focusing on expanding the spatial capabilities of the hybrid technology by employing a 6-axes robotic arm as the extrusion head carrier. We believe that the technology has the potential to produce exciting developments in several fields such as optics, sensors and micro-fluidics.




Schematic of the fabrication process: (a) mixing of the photocurable ink (centrifugal mixer); (b) hybrid printing process (extrusion + UV curing); (c) heat treatment. Comparison between (d) 3D model, (e) printed (green state) and (f) sintered honeycomb sample.

Materiali

*Materials*

CerAMglass
Research Group



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Research output from the project
"Hybrid Freeforming Extrusion
UV Assisted Additive Manufacturing Methods
for the Fabrication of Ceramic Components
with High Complexity", under the SID2020 program.
Financial support provided by D. Swarovski KG.

Published work: De Marzi, A.; Giometti, G.;
Erler, J.; Colombo, P.; Franchin, G.:
Hybrid additive manufacturing for the fabrication
of freeform transparent silica glass components.
Additive Manufacturing 54 (2022). 102727.

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

Ingegneria dei Sistemi Elettrici

*Electrical Systems*

**DII research group**

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This research is developed in cooperation with Fantic Motor S.P.A.

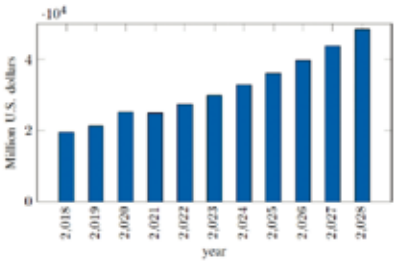
# Design of e-bike electric motor with high efficiency and high power density

In recent years, the mobility sector is undergoing a revolution, which is resulting also into a worldwide spread of light Electric Vehicles (EVs), such as electric scooters and bicycles. The increasing public concern about environmental problems further feeds this revolution. E–bikes are a new trend which fits different riders needs. In fact, they offer extended range and ease of use, allowing riders to travel in urban centers, but also to take longer trips. Electric motor assistance helps with hills, slopes, and rough terrain, allowing for a smoother ride. Thus, younger riders generation is embracing this technology.

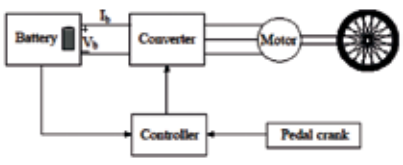
E–bikes are currently the most popular bikes on the market and their popularity is constantly rising. The e–bike global market has experienced a rapid growth from 2018 to 2028. In 2018 the market reached about USD 20 billion, up to USD 25 billion in 2021. The annual growth rate forecasted is equal to about 10 percent between 2021 and 2028, reaching USD 48.5 billion in 2028, almost twice the 2021 market size.

The actual trend is to develop high–performance e–bike traction motors that exhibit high torque density, especially at low speeds. Considering this, Permanent Magnet Synchronous Motors (PMSMs) are the most suitable motors. To satisfy the high power density constraint, high-energy rare-earth Permanent Magnets (PMs) are typically employed.

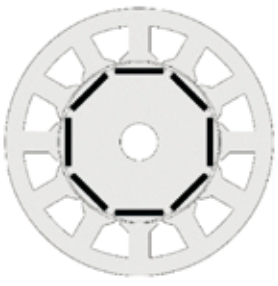
The research project is focused on the development of an innovative e-bike system. Main targets are the reduction of the drive unit weight and of noise, the increase of torque and power density and the maximization of the overall system efficiency.




Projections for the global e-bike market between 2018 and 2028.




General block-scheme of an e-bike system.



Interior Permanent Magnet (IPM) Synchronous motor model.

Fantic e-Mountain Bike Trail, model XTF 1.5 Carbon Sport.

Main research topics:

- IDesign of electrical drives
- Design of electrical machines
- High efficiency power drive system
- Green power conversion

# Identification of critical units for preventive and predictive maintenance in a Major Accident Plant

The Ageing of the equipment is a theme of crucial importance in the management framework of Major Accident Hazards. This concept not only means the time elapsed from the date of the manufacturing or commissioning, but it is also determined by the equipment condition and its deterioration over time. Ageing leads to an increment of the risk connected to the failure occurrence and loss of containment. For this reason, a policy regarding the prevention of Major Industrial Hazard is required by the Seveso Directive according to the D.Lgs. n. 105/2015.
This objective can be achieved by developing and elaborating a well-thought-out preventive and predictive maintenance plan. The idea is to implement a strategy to gain the peculiar advantages of these two policies.
In this framework, a critical assessment method was developed to classify all the plant items according to their inherent risk level. The associated level was determined through a unified risk matrix in which safety, economic and ageing-related aspects were simultaneously considered:

- Safety: operating conditions (pressure, temperature, material inherent hazard, physical state) and failure effect (explosion/fire, gas/liquid release of toxicant, runaway reaction)
- Economic: loss of production, maintainability (accessibility, availability, competence of maintenance operator)
- Ageing: operating conditions (material compatibility, weather effects, critical temperature for corrosion and thermal stresses), deterioration mechanism (age, annual operating hours, lining, results of thickness inspection, glass-line control).

The methodology was developed in collaboration with Finchimica S.p.a., a leading manufacturer of high-tech chemical molecules for crop protection. It has been successfully applied to Finchimica's plant in Manerbio (Italy) and has updated inspection and monitoring frequencies, integrating the results into the current maintenance plan.
Manerbio's factory is the largest integrated plant in the world for the production of dinitroanilines.

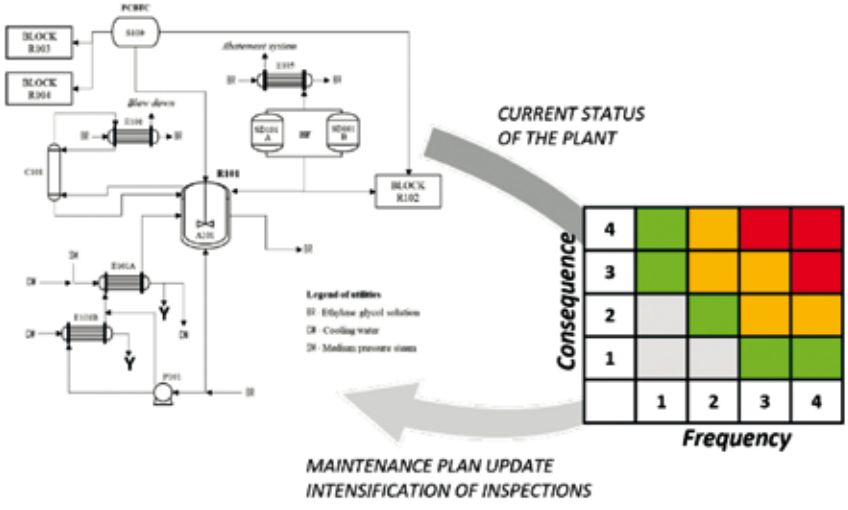



Figure 1. Conceptual overview of the methodology.

Sicurezza ambientale e industriale
*Environmental and industrial safety*

DII research group

Safety Group

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This work has been performed in collaboration with Finchimica S.p.a. (Manerbio, Italy).

FINCHIMICA
TRUST IN AGROSCIENCE

Main research topics:

- Industrial process safety
- Modeling of accidental scenarios
- Design of inherently safer processes
- Safety of green technologies

Sistemi elettrici

*Electrical systems*

DII research group

Power systems


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Main research topics:

- Large-scale energy storage in the network
- EHV/HV dc and ac innovative transmission lines, e.g. insulated cables and gas insulated lines
- Synergy between railway and highway infrastructures and insulated cables
- Multiconductor cell analysis (MCA) of asymmetric systems by means of self-implemented matrix procedures
- Smart grids: the operation and control of active networks
- Voltage regulation in the distribution network with high penetration of distributed generation

# A Novel Three-Phase Power-Flow Algorithm for Transmission Networks

In real power systems the hypothesis of perfectly balanced three–phase network cannot be achieved. This assumption, combined with the increasing in electricity demand, makes the power quality evaluation crucial in power systems. Furthermore, the voltage unbalance in transmission levels has an impact on the sub–transmission and distribution ones. This fact may cause unwanted phenomena, such as early grid protection interventions and electrical machine overheating, which reduce reliability, quality and efficiency of entire power system. This industrial issues make the TSOs interested in the voltage unbalance monitoring/evaluating. For this purpose, a novel three–phase power–flow algorithm, named ad PFPD_3P (Power Flow of the University of Padova 3 Phase), is presented by the Laboratory of Electric Energy Transmission of the University of Padova. Thanks to the representation of slack bus as quasi–ideal current source at positive sequence, PFPD_3P allows exploiting a compact matrix approach in order to achieve more rapidly and easily the power flow solution. Starting from these assumptions a hybrid approach (phase/sequence frame of reference) is developed. The algorithm is easily self–implementable, since only five matrix iterated formulae are employed. PFPD_3P allows considering the real network unbalance by exploiting the MCA (Multiconductor Cell Analysis) method for multiconductor line modelling, and its repercussion on the system unbalance. In order to validate PFPD_3P with a reliable software benchmark, all the analysed networks, for instance the one represented in Fig. 1, are also tested in the commercial software DGS (DIgSILENT PowerFactory). All the power flow solution differences between PFPD_3P and DGS are assessed, and maximum differences of the orders of magnitude equal to 10–3 p.u. for the phase magnitudes and of 10-2 deg. for the phase angles are found. PFPD_3P allows evaluating the impact of possible strategies to mitigate the voltage unbalance (in particular phase transpositions for the lines, network reinforcements and synchronous compensator installations) as reported in Fig. 2. These evaluations are increasingly important for the challenging future networks. All the balanced grid elements, such as generators, transformers, loads, are modelled by means of the sequence approach. Furthermore, loads can be thought as composed of three different types: asynchronous load, the static, and the reactive power compensation devices. So, it is possible to analyse how load composition affects the unbalance factors of the system.

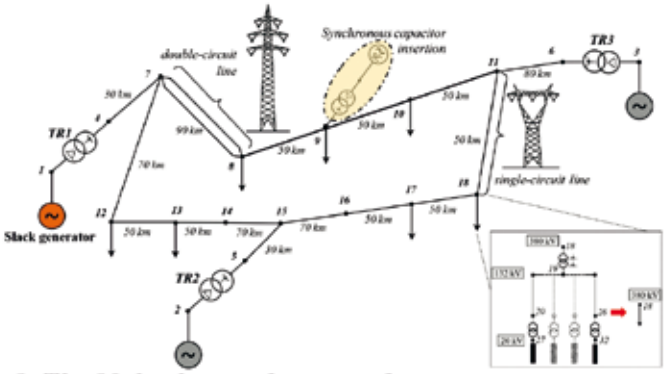



***Fig. 1. The 18–busbar grid case study.***

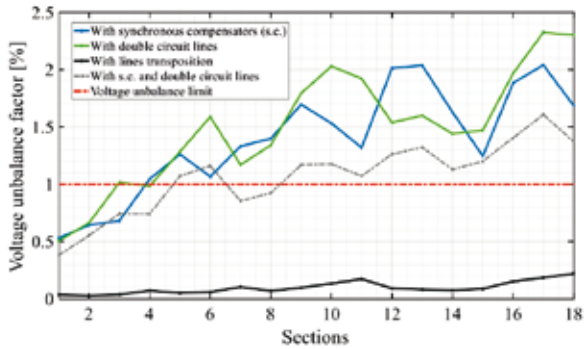


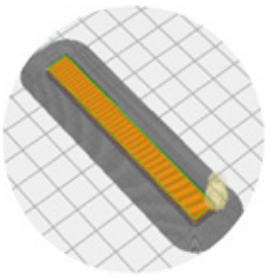

***Fig. 2. Voltage unbalance factor curves.***

# Progetto SAFE: Smart creAtivity for saFety and rEstart

Il gruppo di ricerca in Ingegneria dei Polimeri (PEG), diretto dal Prof. Modesti, in collaborazione con alcune delle principali aziende produttrici di scarponi da sci del distretto Sportsystem di Asolo e Montebelluna, partecipa al progetto SAFE . Il progetto, finanziato dalla regione Veneto tramite i bandi POR FESR 2014-2020, prevede una collaborazione congiunta tra aziende strategiche del territorio e enti di ricerca universitari. L'attività del gruppo di Ingegneria dei Polimeri si inserisce nel contesto Smart Manufacturing e punta all'integrazione di tecnologie intelligenti e materiali innovativi entro i sistemi di progettazione e produzione delle aziende coinvolte. L'obbiettivo di tale attività è sia quello di promuovere la conversione dei sistemi produttivi tradizionali verso un contesto di industria 4.0, sia di supportare le aziende coinvolte per favorirne una ripartenza efficace, a seguito dell'emergenza sanitaria, e una maggiore resilienza verso le problematiche ad essa connesse.

In particolare, il contributo fornito dal gruppo PEG, ha riguardato l'ambito dell'Additive Manufacturing relativamente allo sviluppo di materiali polimerici da stampa 3D in grado di performare analogamente ai rispettivi materiali standard da stampaggio ad iniezione. Durante la prima fase del progetto, terminata a fine 2021, è stata svolta una indagine relativa sia alla identificazione di tecnologie di stampa 3D che di materiali commerciali. Attraverso un'estensiva campagna sperimentale, è stato possibile evidenziare i principali limiti nel comportamento di tali materiali come fase propedeutica al successivo sviluppo del progetto. L'approccio adottato, per la seconda parte del progetto, prevede sia l'adattamento di materiali tradizionali alle più idonee tecnologie di stampa 3D, in relazione alle caratteristiche di prodotto finale, che lo sviluppo di nuovi materiali mediante melt compounding tra polimeri diversi o con l'impiego di opportuni additivi funzionali. Tali materiali verranno quindi valutati sia in termini di performance che lavorabilità al fine fornire una valida soluzione di prototipazione funzionale.

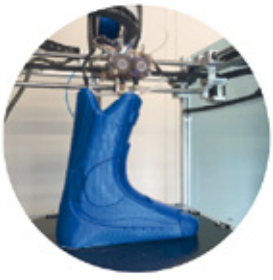
Produzione filamento



Stampa 3D materiale

Caratterizzazione materiale

Modello CAD



Scarpone 3D

Test meccanico scarpone

***Speciale***

**DII research group**

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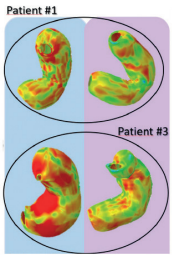
Polymer Engineering Group

POR 2014/2020 FESR / REGIONE DEL VENETO
UNIONE EUROPEA

Main research topics:

- Riciclo fisico e chimico di materiali polimeri
- Stabilità termica e comportamento al fuoco dei materiali polimeri
- Sintesi e caratterizzazione di materiali polimerici espansi
- Nanocompositi a matrice polimerica
- Studio del processing di polimeri e biopolimeri;
- Membrane nanostrutturate a base nanofibre (electrospinning-electrospraying) e loro applicazione nel settore

# Cover story




Mappe della distribuzione delle deformazioni sulla parete gastrica nel caso di pazienti bariatrici in seguito a simulazione di insufflazione, prima e dopo procedura chirurgica di "tubulizzazione" dello stomaco. Le geometrie sono paziente-specifiche e ottenute da risonanza magnetica. I modelli computazionali permettono di implementare e valutare "in silico" numerose varianti di intervento, limitando i test su modello animale e/o le sperimentazioni cliniche. L'obiettivo consiste nel trovare il miglior intervento paziente-specifico, ossia quella conformazione dello stomaco che permetta una corretta stimolazione meccanica della parete gastrica, collegata tramite meccano-recettori alle regioni cerebrali adibite alla regolazione del senso di sazietà.

**Ilaria Toniolo**

È laureata in Ingegneria Biomedica ed in Bioingegneria presso l'Università degli Studi di Padova. Ha conseguito il Dottorato in Industrial Engineering nel 2022 con un progetto che prevedeva lo sviluppo di uno strumento clinico computazionale per la ottimizzazione di procedure bariatriche per il trattamento di persone con severa obesità, attraverso un approccio sperimentale e computazionale accoppiato. Attualmente è assegnista di ricerca presso il Dipartimento di Ingegneria Industriale, per lo svolgimento di attività sia sperimentali sia computazionali per l'analisi in vitro ed in silico della funzionalità meccanica delle vie urinarie inferiori e di affidabilità di sfinteri artificiali.

**www.dii.unipd.it**

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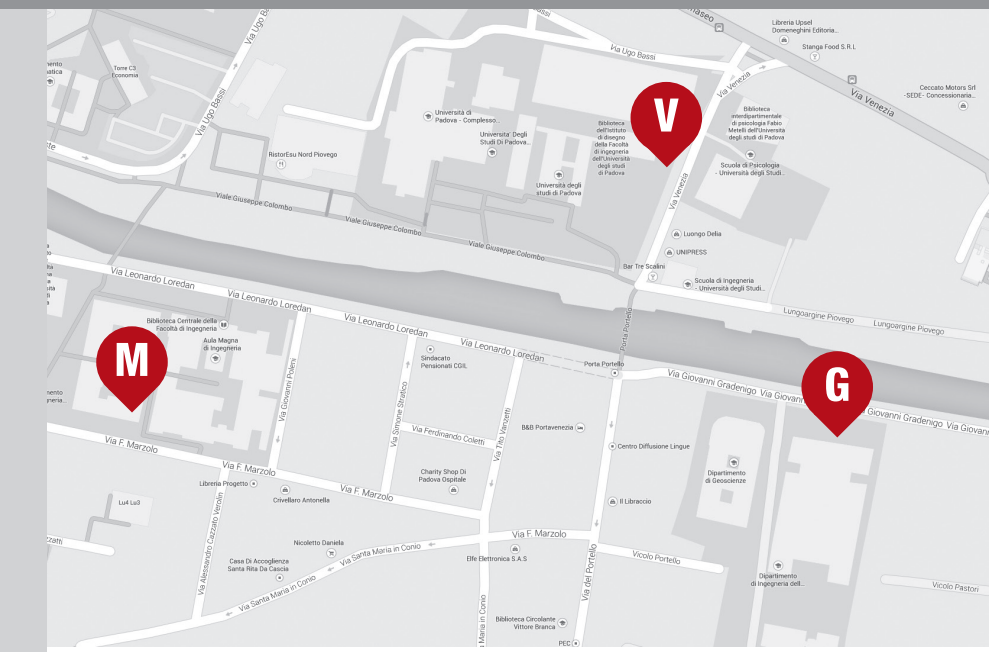


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