Experimental solution utilizing solid oxide fuel cells for waste-to-energy conversion

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Biogas production helps promote the **circular economy** by valorizing waste and reducing the amount of material sent to landfills. The energy obtained from the biomass → biogas → electricity and/or thermal agent chain is **renewable energy**. This is because the CO_2 released into the atmosphere when biogas burns comes from CO_2 assimilated by plants during their growth, or from feed consumed by animals. According to the Kyoto Protocol, this CO_2 is recirculated in a **closed loop**, unlike CO_2 from burning fossil fuels (natural gas, coal, crude oil). The combustion of fossil fuels releases CO_2 that was assimilated in prehistoric times, which is considered an addition to the current atmosphere. The use of biogas as fuel in energy conversion devices, such as **solid oxide fuel cells (SOFCs)**, has been reported for **stationary applications**. Furthermore, high-temperature operation offers the possibility of utilizing the heat for cogeneration cycles. However, there are still challenges with SOFCs operation that need to overcome obstacles to become a widely implemented technology.

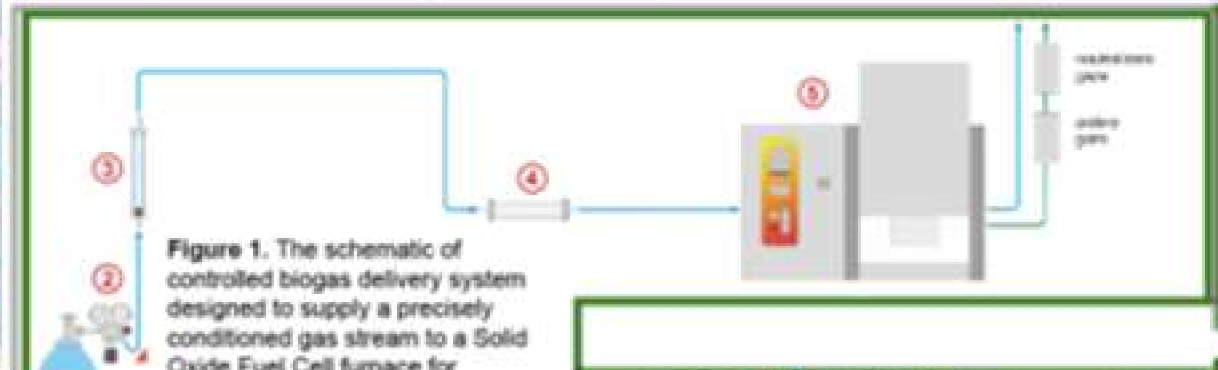
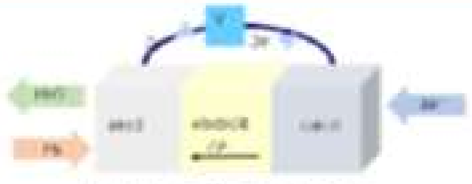


Figure 1. The schematic of controlled biogas delivery system designed to supply a precisely conditioned gas stream to a Solid Oxide Fuel Cell furnace for operational purposes, with provisions for safe exhaust gas handling.
1. gas cylinder
2. pressure reducer
3. flow meter
4. dehumidifier
5. SOFC furnace

Beyond the SOFC furnace: gas neutralization, gas combustion.



Anod: $H_2 + O^{2-} \rightarrow H_2O + 2e^-$
Catod: $½ O_2 + 2e^- \rightarrow O_2^-$

Figure 2. The basic structure of a Solid Oxide Fuel Cell (SOFC).

Figure 3. Synthesis process steps:
a) precursor preparation
b) hydrothermal synthesis
c) solution after hydrothermal process
d) heat treatment / calcination

Key stakeholders:

► **Government & municipalities**: i) ministry of energy; ii) ministry of environment; iii) local municipalities which are key for waste management policies, zoning, and permitting.
► **Waste management companies:** i) operators of landfills, ii) recycling centers, iii) organic waste collection services, iv) feedstock providers.
► **Local communities:** i) beneficiaries of cleaner environments, ii) decentralized energy, iii) potential job creation.

Product and solution offerings:

► **Distributed power generation** for a) communities, b) industrial parks, c) agricultural facilities, d) waste-to-energy plants by converting organic waste, e) agricultural residues, f) sewage sludge into electricity and heat, g) combined heat and power (CHP) units for various industries, h) micro-grids, i) off-grid power solutions.
► **Decentralized energy generation** in rural areas, industrial sites with organic waste, municipalities seeking sustainable waste management and energy solutions.

Impact of a SOFC-biogas setup:

► **Economic Impact:** ▪ **Cost savings** for facilities utilizing on-site biogas for SOFCs can significantly reduce or eliminate reliance on grid electricity and conventional heat sources. ▪ **New revenue stream** since excess electricity generated by the SOFC can be sold back to the grid when grid is connected.
► **Social Impact:** ▪ **Improved public health** by diverting organic waste from landfills reduces unpleasant odors, methane emissions, and the risk of groundwater contamination from leachate. ▪ **Skills development** due to the demand for new technical skills related to fuel cell operation, leading to specialized training and educational opportunities. ▪ **Rural development** by providing economic stability, reducing out-migration, and improving living standards through reliable energy access.
► **Environmental Impact:** ▪ **GHG emission reduction** by generating electricity and heat from biogas displaces the need for fossil fuels, reducing CO_2 emissions. ▪ **Circular economy** by transforming waste into valuable energy and resources. ▪ **Water quality protection** by reducing leachate generation from landfills, thereby protecting groundwater and surface water quality.
► **Technological Impact:** ▪ Drives further **research, development**, and **commercialization of SOFCs**, leading to improved durability, cost reduction, and scalability. ▪ **Fosters expertise** in integrating systems comprising anaerobic digestion, SOFCs, power electronics, and thermal management systems. ▪ **Promotes** the use of advanced sensors and autonomous operation of the systems.

Conclusion: This **SOFC-biogas solution** address critical needs in **decentralized energy generation**, **sustainable waste management**, and **decarbonization across various sectors**, offering practical and economically pathways toward a sustainable future.

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THE INTERNATIONAL EXHIBITION OF SCIENTIFIC RESEARCH, INNOVATION AND INVENTIONS
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Thin film deposition of ZrO_2-xLn_2O_3 compound as a protective layer

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Abstract: The rare earth zirconate (RE-ZrO_2, RE = La, Gd, Sm, Yb, Nd) code name ZrO_2-LSGYN, ceramics were successfully prepared by hydrothermal method (200 °C, 2h, 100 atm). This paper aims to obtain a multilayer oxide structure. The powder was analyzed after heat treatments at 1200 °C and 1500 °C. Then the powder was pressed and sintered in order to obtain targets for EB-PVD deposition equipment. The multilayer oxide architectures were developed by a vacuum thermal evaporation process, on a special installation for obtaining thin film/layer coatings, type EB-PVD (Torr Inc USA). This equipment is equipped with quartz sensors (QCM), for monitoring the deposition rate and a software that allows the creation of complex deposition recipes, keeping the evaporation rate constant. The system is designed to be able to combine several layers, having 4 electron emission guns, with a power of 10 kW/gun. Each gun can be equipped with 4 crucibles in a carousel system, thus allowing a quasi-continuous evaporation of up to 16 different materials. Nimonic plates of 2 sizes were used as well as silicon plates. For better adhesion, NiCrAlY and Al_2O_3 were used as coatings. The acquired films were analyzed using SEM and EDS in the section.

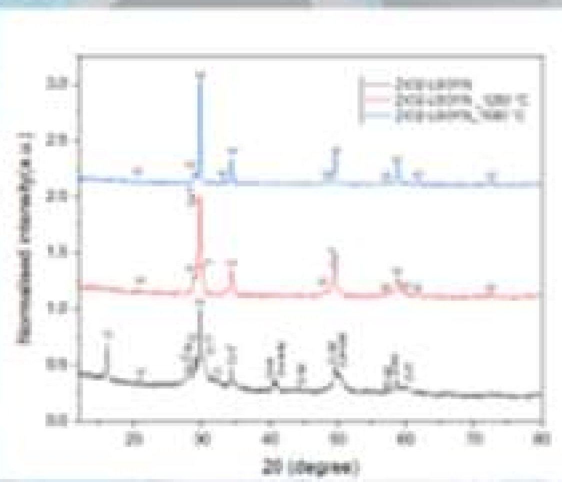

Figure 1: X-ray analysis of ZrO_2-LSGYN

Figure 2: EB-PVD system

Figure 3: NiCrAlY – Al_2O_3 - ZrO_2-LSGYN coatings

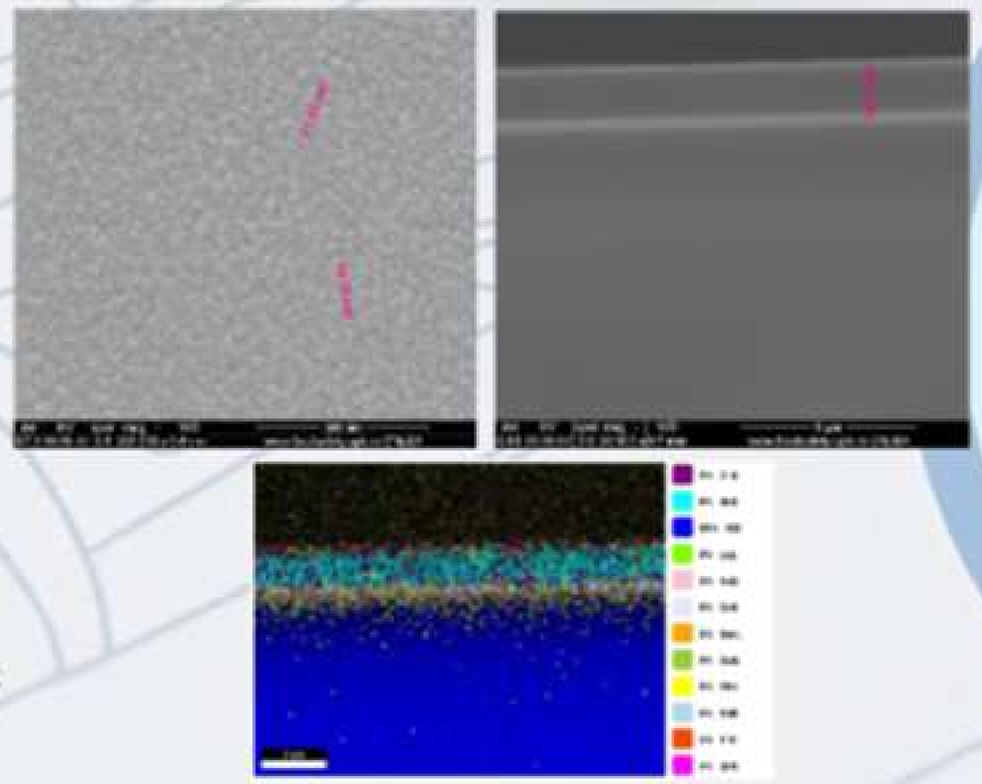

Figure 4: NiCrAlY – Al_2O_3 - ZrO_2-LSGYN coatings: SEM analysis on surface (left) and in section (right), EDS analysis in section (centre)

This type of material is a good candidate for protective coatings in the aerospace industry.

In the future, analyses will be carried out to test corrosion resistance.

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This work was carried out through the Core Program within the National Research Development and Innovation Plan 2022-2027, carried out with the support of MCID, project no. PN 23 25 01 01.

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ADVANCED MANUFACTURING OF NATURE-INSPIRED AND ENVIRONMENTALLY FRIENDLY POROUS CERAMIC STRUCTURES

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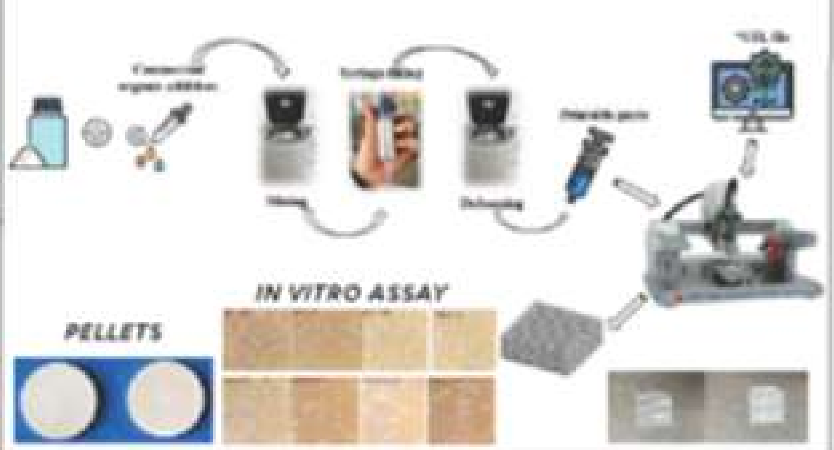
INTRODUCTION

This project explores eco-friendly synthesis and 3D printing of porous bioceramic scaffolds based on ***walstromite*** (***$BaCa_2Si_3O_9$***) and ***baghdadite*** (***$Ca_3ZrSi_2O_9$***). These nature-inspired structures aim to support bone tissue regeneration through improved bioactivity and mechanical performance.

OBJECTIVE

Development of ***innovative***, ***eco-friendly bioceramic scaffolds*** based on walstromite ($BaCa_2Si_3O_9$) and baghdadite ($Ca_3ZrSi_2O_9$) synthesized via **sol-gel** and shaped by **3D printing (robocasting)**. The goal is to obtain **nature-inspired porous structures** with enhanced bioactivity and mechanical properties for **bone tissue regeneration.**



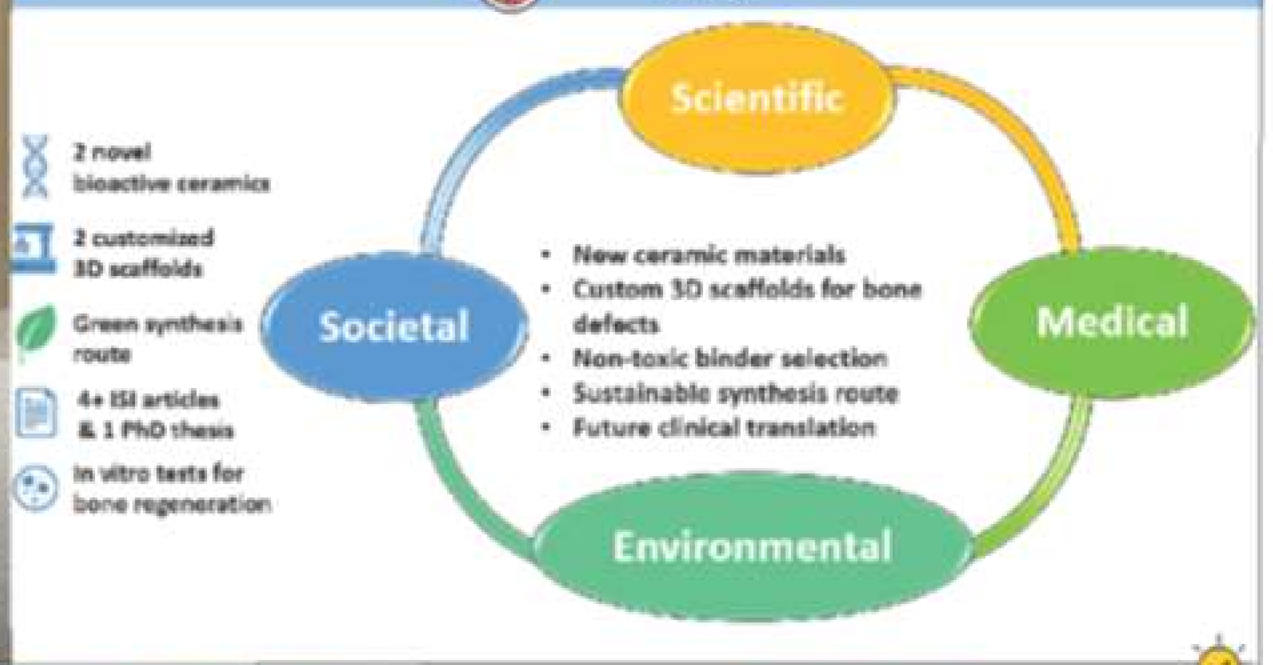
NOVELTY/INNOVATION

- First ***sol-gel route*** to obtain walstromite ($BaCa_2Si_3O_9$) for bone tissue applications.
- First ***robocast (DIW) 3D porous scaffolds*** from Ba-doped (walstromite) and Zr-doped (baghdadite) calcium silicates—beyond photopolymer routes.
- ***Non-toxic binder pastes instead of SLA resins***, addressing medical acceptability and lengthy post-processing.
- **Room-temperature** robocasting with tunable rheology → precise, complex porosity and efficient material use.
- **Performance** aligned with trabecular bone (target compressive strength 0.1–16 MPa) with planned in-vitro cytocompatibility.

APPLICATIONS

- Bone tissue engineering scaffolds for r**epairing critical-size bone defects**
- **Patient-specific** bioactive ceramic **implants** via 3D printing
- **Sustainable medical materials** using non-toxic routes and environmentally friendly processing

IMPACT



STAKEHOLDERS & POTENTIAL BENEFICIARIES

- **Research & Academia** – *IMNR; Universities & labs in ceramics, biomaterials; PhD researchers*
- **Medical Field** - *Hospitals, orthopedic clinics; Surgeons (bone, dental, trauma); testing labs*
- **Industry** - *Implant/device manufacturers; 3D printing & biomaterials startups*
- **Regulators & Funders** - *Romanian Ministry of Education & Research; EU/National funding bodies*
- **End Users / Society** - *Patients with bone loss; NGOs in health & innovation*

CONCLUSION

- This project proposed an advanced, sustainable strategy for the development of novel ceramic biomaterials for bone tissue engineering. By combining eco-friendly sol-gel synthesis with robocasting-based 3D printing, two materials — walstromite and baghdadite — were processed into porous scaffolds with customized architecture.
- The results demonstrate strong potential for clinical translation, addressing key challenges in scaffold design: bioactivity, mechanical compatibility, and environmental safety. The work contributes to the advancement of next-generation implant materials and supports future innovations in regenerative medicine.

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