POLITECNICO DI MILANO

PhD in INGEGNERIA MECCANICA / MECHANICAL ENGINEERING - 39th cycle

PARTENARIATO PNRR Research Field: BINDER JETTING OF METAL MATRIX COMPOSITES FOR CONTINUOUSLY-FED ANODES OF MOLTEN HYDROXIDE DIRECT CARBON FUEL CELLS

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The goal of this research is to redesign the anode of a Molten Hydroxide Direct Carbon Fuel Cell (MH-DCFC) using additive manufacturing (AM), specifically binder jetting (BJ) technology. Currently, the fuel cell is fed in batches, which limits its ability to operate continuously. This requires interrupting the electrical connection to remove the spent fuel. Therefore, a key challenge is to design an innovative anode that can be continuously fed and simultaneously evacuate the spent fuel. Since BJ technology does not use heat to melt the powder bed, it can be used to process metals, ceramics, and composite materials. To improve the efficiency of the DCFC, oxidic catalysts made from iron oxide, lime, and magnesia can be used. Instead of using virgin catalyzer, Red muds (RM), a hazardous and environmentally harmful waste product of alumina production, will be incorporated into the cell design. This will provide a specific application for this waste material, addressing one of the primary alumina industry's major challenges.Metallic (AISI 316L stainless steel) and composite (AISI 316L+RM) anodes will be printed in various geometries, including tea-bag and double helix DNA-like shapes. These anodes will be tested in a laboratory-scale MH-DCFC cell with a traditional configuration that currently uses biochar as fuel. Additionally, an insulating-catalytic coating made from red mud will be deposited on the inner crucible walls to maximize the utilization of red mud in this technology.

	The anticipated outcomes of this research include the development of anodes that can be continuously fed and discharged while utilizing the catalytic properties of the iron oxides present in red muds. The research activity is financed in the framework of the PRIN 2022 PNRR Project **JETCELL** - **Remodelling of advanced fuel cell anodes by binder jetting of stainless steel-red mud composites**, Prot. P20225LHPX, CUP D53D23018060001, PNRR M4C2 I1.1. Norms of Reference: D.D. n. 1409 of 14/09/2022 (call PRIN 2022 PNRR), within the framework of the National Recovery and Resilience Plan, Mission 4 Education and research - Component 2 From research to business - Investment 1.1, funded by the European Union - Next GenerationEU.
Methods and techniques that will be developed and used to carry out the research	The properties of the powder in its pristine, mixed, and used states will be analyzed using granulometry, rheology, and microscopy to determine the optimal feedstock composition and the impact of the printing process. Following curing, debinding, and sintering, the components will be examined using optical and scanning electron microscopy with EDX and EBSD to assess their microstructure. Additionally, X-ray diffraction (XRD) will be used to identify phases and determine the effects of processing on oxide and inclusion development. Vickers microhardness and tensile testing (ASTM E8/E8M) will be used to quantify the mechanical properties of printed parts and evaluate the impact of mixing on component strength. 3D CAD modeling will be employed to design a single batch/tea bag geometry and a continuous feed system to maximize the anode exchange area, thereby enhancing the essential contact between carbon and oxygen for proper cell operation. Specifically, the tea-bag anode will be designed to provide a higher area-to-mass ratio than the metallic mesh tea-bag anode currently used in a reference MH-DCFC developed by the PoliMI. In contrast, the continuous fuel system will be designed from the ground up with a DNA-like double helix geometry to

	optimize fuel flowability by varying the section shape (square, circular, etc.) and helix angle. Fuel cell performance will be evaluated using an AMEL 2553 High Voltage Potentiostat-Galvanostat. Open cell voltage, linear scan voltammetry, and galvanostatic measurements will be conducted in a two-electrode configuration. The inlet tube will serve as the working electrode, while the tea bag anode will act as both the counter and reference electrode. Additionally, a three-electrode configuration will be employed to measure anode and cathode potentials and perform electrochemical impedance spectroscopy. In this configuration, a platinum wire placed midway between the two electrodes will serve as the reference electrode.
Educational objectives	At the end of the PhD cycle the candidate will be able to define, design and carry out original research programs by working in a team or leading a research group in the field of additive manufacturing. Opportunities will be offered for spending visiting periods hosted by project partners for scientific cooperation.
Job opportunities	All project activities are strongly connected to industrial needs and industrial and academic partners are directly participating to project tasks. Our last survey on MeccPhD Doctorates highlighted a 100% employment rate within the first year and a 35% higher salary, compared to Master of Science holders in the same field.
Composition of the research group	1 Full Professors 2 Associated Professors 2 Assistant Professors 3 PhD Students
Name of the research directors	Prof. Nora Lecis, Prof. Davide Mombelli

Contacts
E-mail: nora.lecis@polimi.it, davide.mobelli@polimi.it For questions about scholarship/support, please contact phd-dmec@polimi.it.

Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Financial aid is available for all PhD candidates (purchase of study books and materials, funding for participation in courses, summer schools, workshops and conferences) for a total amount of euro 5.707,13.

Our candidates are strongly encouraged to spend a research period abroad, joining high-level research groups in the specific PhD research topic, selected in agreement with the Supervisor. An increase in the scholarship will be applied for periods up to 6 months (approx. 700 euro/month - net amount).

Teaching assistantship: availability of funding in recognition of supporting teaching activities by the PhD candidate. There are various forms of financial aid for activities of support to the teaching practice. The PhD student is encouraged to take part in these activities, within the limits allowed by the regulations.