Developing Piezoelectric Synthetic Jet Actuators for Application on Short-Take-Off and Landing Aircraft: Celebrating Women in STEM

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In alignment with the International Air Transport Association's goal of net-zero carbon emissions by 2050, global efforts around developing near-term active flow control (AFC) technologies to improve aerodynamic efficiency have intensified[1]. Synthetic jet actuators (SJAs) are an example AFC device that contributes zero net mass flux (ZNMF). Consequently, they are self-contained allowing compact flush-mounting and the generation of fluidic jets without external pneumatic piping. More specifically, piezoelectrically driven SJAs offer enhanced power-specific mass compared to alternative driving mechanisms including electro-active polymers (EAP), loudspeakers, ferromagnetic shape memory alloys (FSMA), and plasma synthetic jets (PSJA)[2].

Unimorph piezoelectric diaphragms consists of one active piezoceramic (e.g. PZT) layer bonded to a compliant brass substrate. The PZT layer undergoes repeated mechanical deformation in response to an applied alternating voltage via the reverse piezoelectric effect. In an 'opposite' configuration (see Fig. 1), the vibrating diaphragm is clamped within a cavity parallel to a circular or slotted orifice. In one cycle, the diaphragm ingests fluid into the cavity during the downstroke and expels the ingested fluid in the subsequent upstroke. The shear layer developed along the orifice walls during fluid expulsion separates at the sharp orifice edge and rolls up into a vortex ring upon exiting. Successive vortex production results in a pulsatile jet that, when situated within a separated boundary layer, injects momentum locally to re-energise the flow and promote reattachment to the lifting surface.

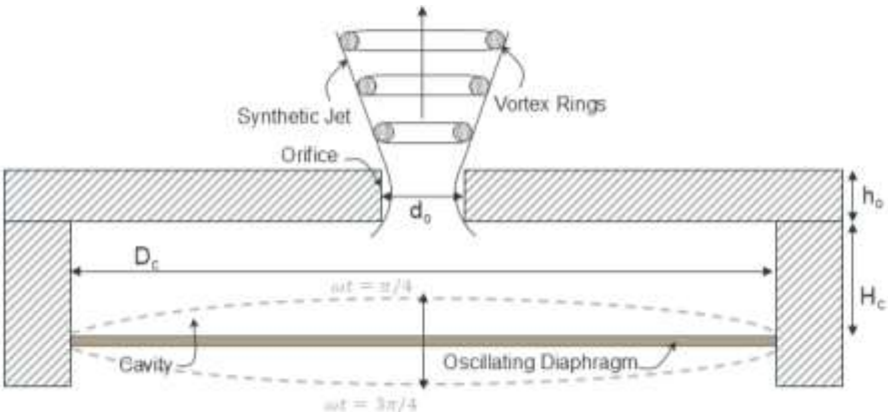

Fig. 1 - Opposite piezoelectric SJA arrangement

Previous work at the University of Nottingham achieved state-of-the-art power conversion efficiencies for piezoelectric SJAs in quiescent (still-air) conditions, reaching jet velocities of 63.2 m/s at an efficiency of 72%[3]. The proposed work aims to extend the performance of such configurations into crossflow conditions representative of Short-Take-Off and Landing (STOL) aircraft environments. In these scenarios, cruise speeds are comparable in magnitude to the synthetic jet velocities currently achievable using piezoelectric drivers. To achieve this, a fully coupled structural–fluidic–acoustic piezoelectric SJA model will be developed, accounting for external crossflow effects through co-simulation between Abaqus and Star-CCM+. This approach enhances existing modelling procedures in the literature, which often oversimplify the problem by imposing an oscillating boundary condition and neglecting coupled multiphysics effects[4,5].

References

[1] B. Gungordu, J. M. and P. A., "Enhancing Jet Velocity and Power Conversion Efficiency of Piezoelectric Synthetic Jet Actuators," *AIAA Journal,* vol. 61, pp. 4321-4331, 2023.

[2] IATA, "IATA AGM Resolution on Net Zero Carbon Emissions," [Online]. Available: https://iata.org. [Accessed 22 April 2025].

[3] M. Jabbal, S. Liddle and W. Crowther, "Active Flow Control Systems Architectures for Civil Transport Aircraft," *Journal of Aircraft,* vol. 47, no. 6, pp. 1966-1981, 2010.

[4] L. Kral, J. Donovan, A. Cain and A. Cary, "Numerical simulation of synthetic jet actuators," in *American Institute of Aeronautics and Astronautics 4th Shear Flow Control Conference*, 1997.

[5] S. Mallinson, J. Reizes and G. Hong, "An experimental and numerical study of synthetic jet flow," *The Aeronautical Journal,* vol. 105, no. 1043, pp. 41-49, 2001.

Celebrating Women in STEM.... 3D-Printed Sodium-Ion Batteries

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This work uses inkjet printing techniques to fabricate sodium-ion cathodes with increased surface areas for enhanced electrochemical performance. Inkjet printing allows for high-resolution (~20 μm) deposition of functional materials, without the need for structural polymeric or resin components, enabling additive manufacturing (AM) of concentrated active materials.

As demand for large-scale renewable-energy storage grows, sodium-ion batteries (SIB) have emerged as a sustainable alternative to lithium due to their low cost, natural abundance, and thermal stability. However, the commercial viability of SIBs must still overcome the significant obstacle of the intrinsically larger size of sodium ions, which imposes fundamental limitations on energy density and rate performance.[1] NASICON (sodium superionic conductors) have been identified as critical compounds for bridging the technological gap due to their robust crystal lattices, offering improved structural integrity, combined with open channels which allow for rapid ionic diffusion.[2] In addition, AM techniques have demonstrated the capability to fabricate innovative 3D electrode architectures which are able to promote more efficient ionic transport by increasing active surface area and reducing ion transport distances.[3,4]

We report on the formulation of a functional $Na_3V_2(PO_4)_3$ (NVP) ink, compatible with inkjet printing techniques (Fig 1. a). Novel inkjet printing methods were developed to prevent the merging of fine structures and allow for rapid manufacture of 3D micro-pillars. Compared to traditional cast electrodes (Fig 1. b), our printed, single-droplet pillars (~250 μm height by ~80 μm width) (Fig 1. c) offered a 766% increase in active surface area, with the resulting increase expected to offer proportional improvements to battery capacity. Both printed and drop-cast versions of the formulation underwent galvanostatic charge-discharge testing and successfully exhibited the characteristic voltage plateau of $Na_3V_2(PO_4)_3$ versus sodium metal, at approximately 3.4 V.

The inkjet-printing techniques presented here not only offer a valuable approach to the development of commercially competitive sodium batteries, but also exhibit significant potential in optimising other electronic, catalytic, and biological materials with surface area dependencies.

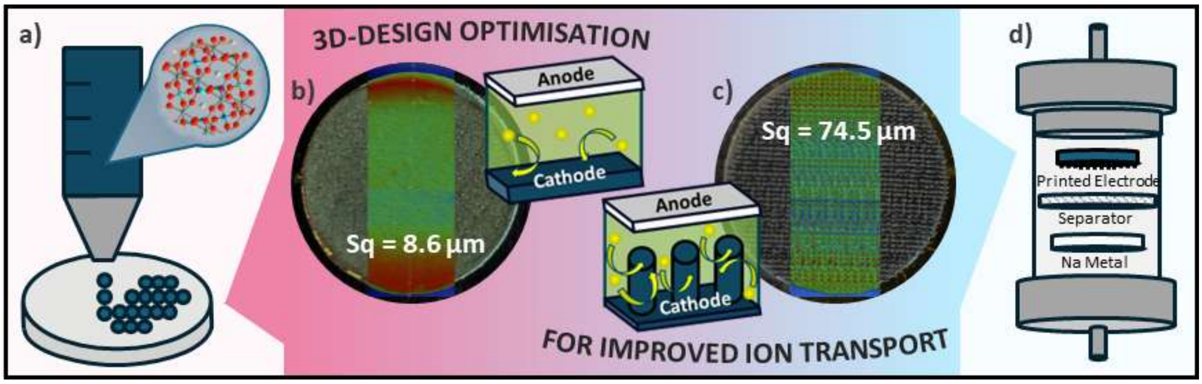

Fig 1. Graphical abstract illustrating a) inkjet printing of functional NVP ink, b) optical image of conventional cast battery materials with optical profilometry overlay, root mean square roughness, and graphical illustration, c) optical image of printed micro-pillars with optical profilometry overlay, root mean square roughness, and graphical illustration, d) Swagelok cell testing of printed cathode materials vs sodium metal.

References

[1]M. M. Mashfy, T. A. Alvy, N. Hossain, T. Sharmin and M. Nasim, *Next Energy*, **2026**, 10, 100478.

[2]S. Banerjee, R. B. Choudhary and S. Ansari, *Future Batteries*, **2024**, 100010.

[3]K. Sztymela, M. Bienia, S. Ziesche, J. Varghese and M. Cerbelaud, *Heliyon*, **2022**, 8, e12623.

[4]M. Mottaghi and J. M. Pearce, *Batteries*, **2024**, 10, 110.

Elucidation of potential factors involved in Extracellular Electron Transfer mechanism in *Cupriavidus necator* H16

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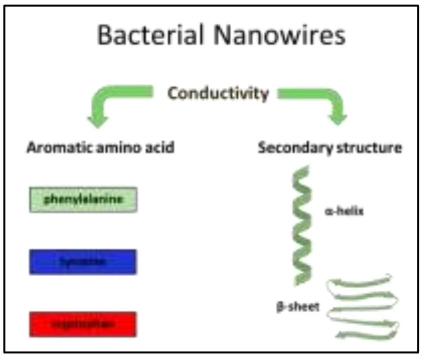
Microbial electrochemical technologies (METs) provide sustainable solutions for energy production, wastewater treatment, and environmental remediation[1]. However, their practical applications are limited by low electron transfer (ET) efficiency. Enhancing natural extracellular electron transfer (EET) mechanisms and reengineering EET pathways in industrially relevant bacteria is therefore essential for advancing MET research. *Cupriavidus necator* H16 (C. nec. H16), a versatile chemolithoautotroph with industrial relevance, has a poorly characterised EET mechanism. This research investigates the factors influencing EET in C. nec. H16 and aims to engineer strains with enhanced ET efficiency.

Previous studies across bacterial systems have shown a strong correlation between the aromatic amino acid content of pilin proteins and their conductivity, with increased aromaticity enhancing EET efficiency[1]. Based on these findings, wild-type (WT) and engineered C. nec. H16 PilA variants incorporating structural truncations and/or aromatic amino acid substitutions were evaluated. Among the tested strains, mPilA T61W, which combines structural truncation with increased aromatic amino acid content, generated the highest potential in dual-chamber microbial fuel cells using sodium gluconate as the electron donor, a trend supported by cyclic voltammetry showing the highest anodic currents. Scanning electron microscopy revealed similar dispersed cell attachment across all strains, indicating that differences in current output arose from pilin modifications rather than variations in biofilm formation.

Ongoing experiments further assess EET efficiency using dual redox mediator systems with potassium ferricyanide as a hydrophilic reporter under aerobic and anaerobic conditions, with glucose and fructose as carbon sources. Linear sweep voltammetry of the ferri/ferrocyanide couple is used to quantify EET, with the percentage change in oxidative current at 425 mV vs. Ag/AgCl providing a comparative measure of ET efficiency across strains and conditions.



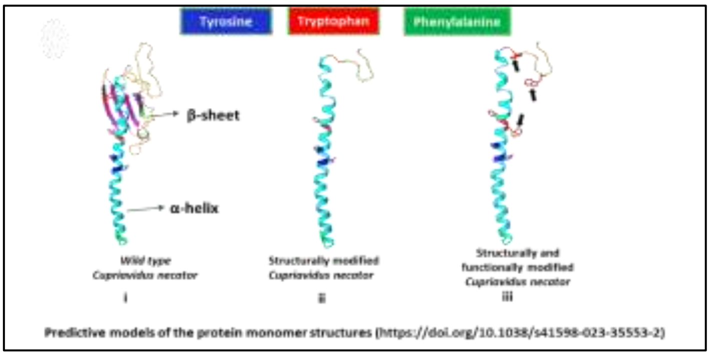


Fig.1 (left)- Conceptual illustration of bacterial nanowire composition. Fig.2 (right): (i)- Model of *Cupriavidus necator (C. nec.* H16*)* wild type (WT) produced by Chimera. Aromatic residues are highlighted as red (tryptophan), blue (tyrosine) or green (phenylalanine) branches; (ii)- Engineered *C. nec.* strains' model produced by Chimera. Aromatic residues are highlighted as red (tryptophan), blue (tyrosine) or green (phenylalanine) branches, and black arrows indicate locations of amino acid mutation[2].

References

1 M. Vargas, N. S. Malvankar, P.-L. Tremblay, C. Leang, J. A. Smith, P. Patel, O. Snoeyenbos-West, K. P. Nevin and D. R. Lovley, *mBio*, 2013, **4**, e00105-00113.

2 B. Myers, F. Catrambone, S. Allen, P. J. Hill, K. Kovacs and F. J. Rawson, *Sci Rep*, 2023, **13**, 8843.

Oral Protein Delivery for the Local Treatment of Crohn's Disease Using Targeted Supramolecular Nanoparticles

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Oral delivery of biologics represents a promising strategy for the local treatment of Crohn's Disease, yet it is hindered by instability at gastric pH, enzymatic degradation and poor permeability. This study builds on recent advances in supramolecular assembly[1] to develop a 'nano-in-gel' system for targeted protein delivery. Nanoparticles were synthesized via pH-mediated complexation of tannic acid and polyethylene glycol 10,000 (PEG 10K), achieving reproducible sub-200 nm sizes. A key finding was the tunability of the system, where increasing tannic acid content significantly reduced particle size, allowing for precise control over physicochemical properties. Future work will integrate these nanoparticles into a pH-sensitive hydrogel for gastric protection and intestinal release. Furthermore, the platform is designed to be adaptable; the incorporation of permeation enhancers can be tuned to the specific disease state of a patient (e.g., active inflammation vs. remission) to strategically modulate epithelial penetration and maximise local therapeutic efficacy.

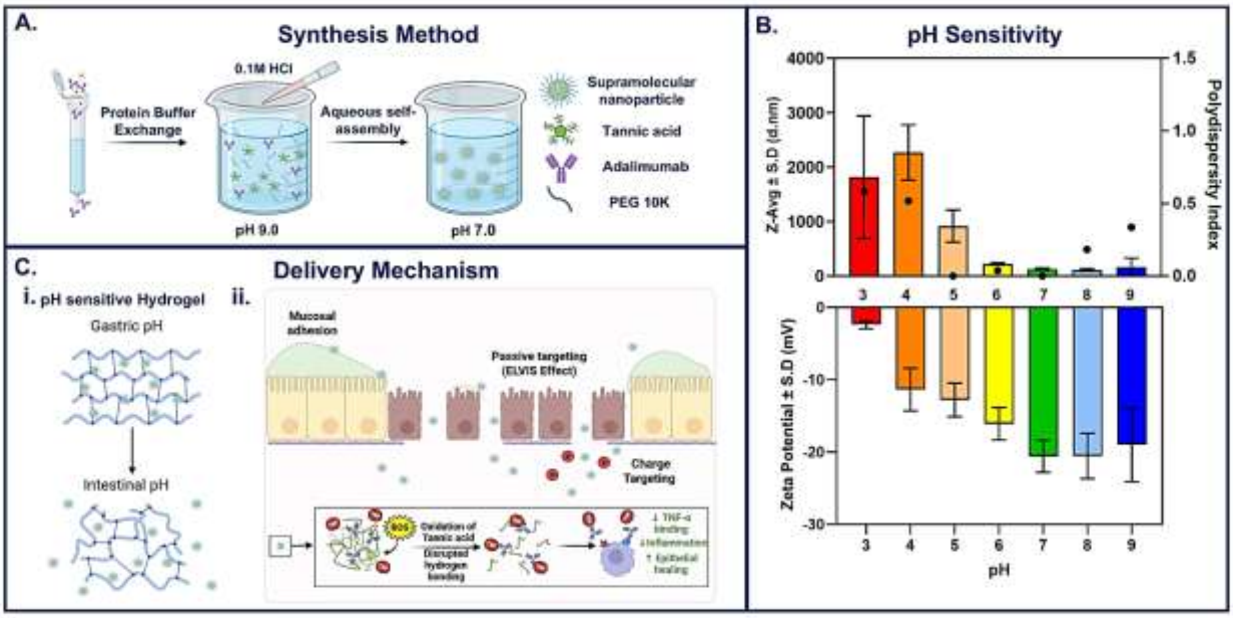

Figure 1: Targeted Supramolecular Nanoparticle Delivery for Crohn's Disease. (A) Synthesis of supramolecular nanoparticles encapsulating adalimumab via pH-driven self-assembly. (B) Electrophoretic and Dynamic Light scattering techniques confirmed the pH-sensitive property of the supramolecular nanoparticle. (C) Proposed delivery mechanism i). Oral delivery of pH-sensitive hydrogel protects and releases nanoparticles upon reaching intestinal pH ii). Nanoparticles target inflammatory lesions via a compromised epithelial barrier and dissociates in response to high Reactive Oxygen Species (ROS) levels for site-specific drug delivery.

References

1. X. Wang, J. Yan, D. Pan, Y, Xu, F. Wang, J. Sheng, X. Li, M. Yang. *Theranostics*. **2020**, 29;10(23):10808-10822

Towards The Development Of Positive Electrodes For High-Energy Full Organic Batteries.

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Organic-based batteries made of redox-active organic materials strike as a promising emerging technology for energy storage.[1] Made of earth-abundant electrode materials, this technology provides structural versatility, high specific capacity and fast multi-electron transfer kinetics.[2] Despite being a valuable alternative to lithium-ion batteries currently dominating the market, a challenge remains in identifying redox-active organic materials with sufficiently high redox potentials (>3.5 V vs Li^+/Li) to achieve energy densities comparable to commercial lithium-ion technologies such as lithium iron phosphate (LFP) based batteries. Most organic electrode materials reported in the literature show lower operating voltages, which limits their practical use in high-energy battery systems.[3]

In this work, 10-methylphenothiazine (MPT) was selected as the redox-active organic molecule due to its high redox potential and multi-electron transfer capability. To address common dissolution issues encountered with small organic molecules, MPT was polymerised to poly(MPT) following a facile synthesis route. Cyclic voltammetry confirmed that poly(MPT) retained its redox properties upon polymerisation with two redox processes at 3.5 and 3.9 V vs Li^+/Li.

Electrochemical testing in half-cell configurations demonstrated that poly(MPT) achieved a discharge capacity of 126 mAh g^{-1}, comparable to that of commercial LFP electrodes, with stable cycling over 10 cycles. This study offers useful insights into how to fabricate electrodes using redox-active organic materials and shows that poly(MPT) can serve as a sustainable alternative for positive electrode applications. It helps move organic materials into functional electrodes and speeds up the development of new energy storage technologies.

References

[1] J. Kim, Y. Kim, J. Yoo, G. Kwon, Y. Ko, K. Kang, *Nat Rev Mater* **2023**, *8*, 54.

[2] C. Gannett, L. Melecio-Zambrano, M. Theibault, B. M. Peterson, B. P. Fors, H. D. Abruña, *Energy*, **2021**, *1*, 1.

[3] J. Bitenc, K. Pirnat, O. Lužanin, R. Dominko, *Chemistry of Materials,* **2024,** *36* (3), 1025-1040.