Poster

# Biological piezoelectric materials as high-performance, eco-friendly structural health monitors

**Krishna Hari[1], Suman Bhattacharya[1], Sarah Guerin[1,2]**

*[1]Department of Physics, Bernal Institute, University of Limerick*

*[2]SSPC, SFI Research Centre for Pharmaceuticals, Bernal Institute, University of Limerick.*

*krishna.hari@ul.ie, suman.s.bhattacharya@ul.ie, sarah.guerin@ul.ie*

In the past ten years, biological piezoelectric materials have emerged as the potential next generation of cost-effective, green electromechanical sensors [1, 2]. The piezoelectric voltages produced under an applied force are inversely proportional to the dielectric constant of the material and so even 'weak' organic piezoelectrics (with modest piezoelectric constants compared to inorganic ceramics [3, 4], can generate large voltages in response to strain. Amino acids are the simplest biological units, and are inexpensive and easy to crystallise [5-7], and demonstrate measurable piezoelectricity in single crystal [8-10] and polycrystalline forms [11, 12].

Recently, we have experimentally validated flexible glycine-based sensors for pipe leak detection and monitoring in real-time, for a variety of flow rates and leak sizes using a custom fluid test rig developed for the validation of PVDF patches [13]. This is the first time that glycine crystals have been grown and characterised as a high-concentration, polycrystalline aggregate for piezoelectric sensing [14]. However, a key limitation of this study is that the piezoelectric response of the film was less than that of glycine single crystals due to the random orientation of glycine crystallites [11].

In this work, we will systematically study the effect of crystallisation growth parameters on a number of polycrystalline amino acid films in order to modulate the piezoelectric response and increase the detection sensitivity and voltage output of amino acid-based piezoelectric devices. Moreover, we will investigate and optimise different parameters involved in the polycrystalline film growth and characterise the formed polycrystalline films using Scanning Electron Microscopy, X-Ray Diffraction, and Scanning Probing Microscopy. The study will highlight the potential of low-dielectric, non-centrosymmetric biomolecular crystal films for widespread monitoring of built infra-structure systems by showing how reliably and sustainably they may be used as sensors for pipe structural health monitoring (SHM) applications.

[1] Guerin, S.; Tofail, S. A.; Thompson, D., Organic piezoelectric materials: milestones and potential. NPG Asia Materials 2019, 11 (1), 1-5.

[2] Chorsi, M. T.; Curry, E. J.; Chorsi, H. T.; Das, R.; Baroody, J.; Purohit, P. K.; Ilies, H.; Nguyen, T. D., Piezoelectric biomaterials for sensors and actuators. Advanced Materials 2019, 31 (1), 1802084gilies, L., Kramer, M. J., McCallum, R. W., Kycia, S., Haeffner, D. R., Lang, J. C. & Goldman, A. I. (1999). Rev. Sci. Instrum. 70, 3554.

[3] Zhang, S.; Xia, R.; Shrout, T. R., Lead-free piezoelectric ceramics vs. PZT? Journal of Electroceramics 2007, 19 (4), 251-257.

[4] Panda, P.; Sahoo, B., PZT to lead free piezo ceramics: a review. Ferroelectrics 2015, 474 (1), 128-143.

[5] Vijayan, N.; Rajasekaran, S.; Bhagavannarayana, G.; Ramesh Babu, R.; Gopalakrishnan, R.; Palanichamy, M.; Ramasamy, P., Growth and characterization of nonlinear optical amino acid single crystal: L-alanine. Crystal growth & design 2006, 6 (11), 2441-2445.

[6] Hod, I.; Mastai, Y.; Medina, D. D., Effect of solvents on the growth morphology of DL-alanine crystals. CrystEngComm 2011, 13 (2), 502-509.

[7] Moitra, S.; Kar, T., Growth and characterization of L-valine-a nonlinear optical crystal. Crystal Research and Technology: Journal of Experimental and Industrial Crystallography 2010, 45 (1), 70-74.

[8] Guerin, S.; Stapleton, A.; Chovan, D.; Mouras, R.; Gleeson, M.; McKeown, C.; Noor, M. R.; Silien, C.; Rhen, F. M.; Kholkin, A. L., Control of piezoelectricity in amino acids by supramolecular packing. Nature materials 2018, 17 (2), 180-186.

[9] Kumar, R. A.; Vizhi, R. E.; Vijayan, N.; Babu, D. R., Structural, dielectric and piezoelectric properties of nonlinear optical γ-glycine single crystals. Physica B: Condensed Matter 2011, 406 (13), 2594-2600.

[10] Heredia, A.; Meunier, V.; Bdikin, I. K.; Gracio, J.; Balke, N.; Jesse, S.; Tselev, A.; Agarwal, P. K.; Sumpter, B. G.; Kalinin, S. V., Nanoscale ferroelectricity in crystalline γ-glycine. Advanced Functional Materials 2012, 22 (14), 2996-3003.

[11] Guerin, S.; Tofail, S. A.; Thompson, D., Longitudinal Piezoelectricity in Orthorhombic Amino Acid Crystal Films. Crystal Growth & Design 2018, 18 (9), 4844-4848.

[12] Guerin, S.; O'Donnell, J.; Haq, E. U.; McKeown, C.; Silien, C.; Rhen, F. M.; Soulimane, T.; Tofail, S. A.; Thompson, D., Racemic amino acid piezoelectric transducer. Physical review letters 2019, 122 (4), 047701.

[13] Okosun, F.; Cahill, P.; Hazra, B.; Pakrashi, V., Vibration-based leak detection and monitoring of water pipes using output-only piezoelectric sensors. The European Physical Journal Special Topics 2019, 228 (7), 1659-1675.

[14] Okosun, F.; Guerin, S.; Celikin, M.; Pakrashi, V., Flexible amino acid-based energy harvesting for structural health monitoring of water pipes. Cell Reports Physical Science 2021, 2 (5), 100434.