Integration of 2D Materials with Textiles for Wearable Electronics and Beyond

Monica F. Craciun
E Kovalska[a], A Neves[a], S Russo[a], K Sreeja Sadanandan[a], A Bacon[a], DW Shin[a], SFR Alkhalifa[a], G Rajan[a], E Torres Alonso[a], C Murphy[a], I Grikalaite[a], Z Saadi[a], LT Lam[a], HA Pocinho[b], DM Caetano[b], H Alves[b], R Mastria[c]
[a] *University of Exeter, North Park Road, EX4 4QF Exeter, United Kingdom*
[b] *Instituto de Engenharia de Sistemas e Computadores - Microsistemas e Nanotecnologias, Lisbon 1000-029, Portugal*
[c] *Institute of Nanotechnology, CNR NANOTEC, c/o Campus Ecotekne, via Monteroni, I-73100 Lecce, Italy*
m.f.craciun@exeter.ac.uk

2D materials, with exceptional electrical conductivity and mechanical flexibility, are emerging systems for wearable electronics and smart textiles, offering opportunities for the seamless incorporation of electronic devices in textiles. In this talk, I will give an overview of our recent progress in integrating 2D materials with textile substrates, encompassing fibres and fabrics, for a range of textile electronics applications, including wearable sensors and energy harvesting devices, and textile environmental sensors.

We developed a versatile technique to coat common insulating textile fibres like polypropylene, polylactic acid, polyethylene, and nylon with monolayer and few-layer graphene [1,2] via Chemical Vapor Deposition (CVD). These graphene-coated fibres exhibited low sheet resistance, preserving graphene's conductivity and enabling the integration of touch-sensitive and light-emitting devices into textiles [3]. We have also used these fibres as temperature sensors in a low-voltage carbon-graphene e-textile system [4].

In the area of fabric-based wearable devices, a pivotal obstacle lies in seamlessly integrating electronics into fabrics while preserving their softness and comfort. A crucial aspect involves achieving electrically conductive coatings on textiles that adapt to the irregular and coarse structures of fabrics without compromising their properties. We introduced a straightforward, cost-effective, and highly scalable method, the ultrasonic spray coating [5]. This technique was effectively used to coat various types of textile fabrics such as meta-aramid, polyester, and nylon using water-based suspension of graphene and create fabric electrodes displaying good conductivity, and resilience to bending, compression and tension. We further demonstrated the application of these graphene conductive fabric electrodes in self-powered sensing technologies embedded in textiles [6,7]. The steppingstone for these advances is a new class of triboelectric energy harvesters able to convert presently unused sources from our living environment such as sounds and vibrations into electrical energy [8]. Due to the conformation ability of the triboelectric sensors, they were implemented on key moving parts of the human body and used to monitor biomechanical motion through electrical signals [6, 7]. The self-powered sensors demonstrate their potential for wearable bioelectronics, intelligent robotics, prostheses, and rehabilitation purposes. Finally, we demonstrated the use of graphene on fabrics for a novel textile-integrated triboelectric nanogenerator capable of sensing and harvesting low-frequency acoustic energy [8].

References

[1] A. Neves, et al., Sci. Rep. 5 (2015) 9866.
[2] A. Neves, et al., Sci. Rep., 7 (2017) 4250.
[3] E. Torres Alonso, et al, npj Flexible Electronics, 2 (2018) 25.
[4] G Rajan, et al., ACS Appl. Mater. Interfaces, 12 (2020) 29861.
[5] K Sreeja Sadanandan et al., J. Phys. Mater., 4 (2021) 014004.
[6] Domingos I, et al., Nano Energy, 115 (2023) 108688.
[7] K Sreeja Sadanandan et al, Nano Energy, 116 (2023) 108797.
[8] Kovalska E. et al, Nano Energy, 120 (2024) 109109