Graphene-based technologies by solution processing

Andrea CAPASSO - *International Iberian Nanotechnology Laboratory, Braga, Portugal*

Graphene and 2D crystals can be applied in various technologies, including energy harvesting/storage, water purification, and sensing. Sustainable and scalable manufacturing processes are still required to transition these materials from the lab to the market. Liquid phase exfoliation techniques hold potential for a cost-effective, large-scale production, but most of them related to scalability and reliance on hazardous solvents like NMP and DMF. Here we propose green approaches to exfoliate graphite into atomic-thick pristine graphene flakes, focusing on alternative, non-toxic solvents (*e.g.*, water and Cyrene) and scalable exfoliation techniques (*e.g.*, high shear mixing and high-pressure airless spray). Graphene flakes dispersions are used to make composites and fabricate proof-of-concept membranes for nanofiltration and micro-supercapacitors.

Graphene-based nanofiltration membranes are fabricated by vacuum filtration onto porous PDVF supports The µm-thick graphene laminates are made of interconnected nanochannels carrying a positive charge. The PVDF/graphene membranes are mechanically robust and retain their structure without any swelling for extended operation time in water (up to six months). Ion transport experiments reveal selective behavior based on size and charge, while studies involving antibiotic diffusion demonstrate rejection rates exceeding 95%.

A conductive, sustainable, all-carbon composite paste based on the graphene flakes is designed. When cast by blade coating, it exhibited strong adhesion and thickness-dependent sheet resistance (reaching as low as 7 Ω/□ for a 50-µm coating). Interdigitated micro-supercapacitors electrodes are deposited on flexible PET and covered with a PVA/H_2SO_4 gel electrolyte. The supercapacitors achieve a Coulombic efficiency close to 100%, with areal and volumetric capacitances of 6.16 mF cm^{-2} and 2.46 F cm^{-3}, respectively. The maximum energy density exceeds 200 µWh cm^{-3} with 91.5% capacitance retention after 10000 Galvanostatic charge-discharge cycles. The mSCs retain the same performance when subjected to bending and can be easily modularized to adjust the voltage and capacitance outputs.

The versatility of the paste is further demonstrated through the creation of high-performance coatings for electromagnetic interference shielding and wearable strain sensors.