Shear exfoliated few-layer graphene and cellulose nanocrystal composite as promising anode for bioelectrochemical cell

Sara Lund
Laura T. Wey, Elisabeth Björnvik, Qingbo Wang, Xiaoju Wang, Sindhujaa Vajravel, Yagut Allahverdiyeva, Jan-Henrik Smått, Jouko Peltonen, Rose-Marie Latonen and Tom Lindfors
Åbo Akademi University, Laboratory of Molecular Science and Engineering, Henriksgatan 2, 20500, Turku (Åbo), Finland
University of Turku, Molecular Plant Biology, 20014 Turku, Finland
sara.h.lund@abo.fi

Electroconductive composites of graphene and cellulose nanocrystals (CNC) were prepared by direct exfoliation of natural flake graphite in CNC suspensions. Using the previously optimized and scalable high-shear exfoliation method [1], it was shown that the environmentally friendly CNC is an excellent graphene stabilizer as we prepared aqueous graphene-CNC dispersions with a high concentration (4.0 mg ml^{-1}) and yield (4.0 %) after only 2 h exfoliation time. These highly concentrated graphene-CNC dispersions were readily spray-coated on non-conductive substrates to form robust composite films. Albeit the insulating nature of CNC, the spray-coated composite films were electrically conductive with conductivity up to 280 S m^{-1}, depending on the CNC amount. Cyclic voltammetry measurements showed a reversible redox response for the $Fe(CN)_6^{3-/4-}$ couple proving that the electron transfer was efficient in the composite film. Furthermore, biocompatibility studies with photosynthetic microorganisms revealed no toxic effects as the cells maintained their photosynthetic performance and growth when placed in direct contact with the composite. Due to its biocompatibility, electroactivity and good water-stability, the composite film has been investigated as an anode material for a biophotovoltaic (BPV) device. In BPV devices, photosynthetic microorganisms such as cyanobacteria convert solar energy into electricity. Due to the abundance of the composite source materials and the efficiency of the fabrication method, the graphene-CNC composite offers a sustainable immobilization matrix for the cyanobacterial cells creating a functional bioanode for the BPV cell.

References

[1] S. Lund, J. Kauppila, S. Sirkiä, J. Palosaari, O. Eklund, R.-M. Latonen, J.-H. Smått, J. Peltonen, T. Lindfors, Carbon. 174 (2021) 123–131.

Figures

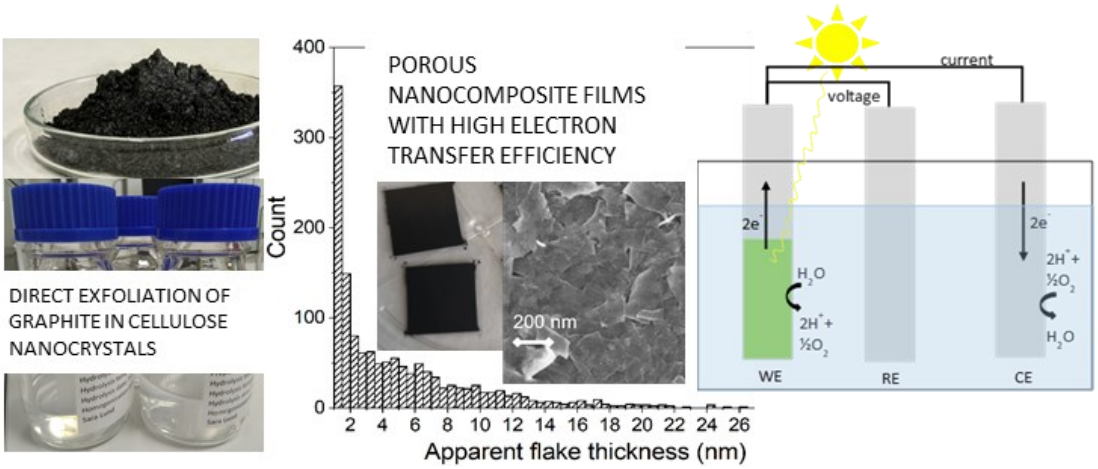

Figure 1: A composite film of graphene and cellulose nanocrystals and a schematic presentation of a three-electrode biophotovoltaic system