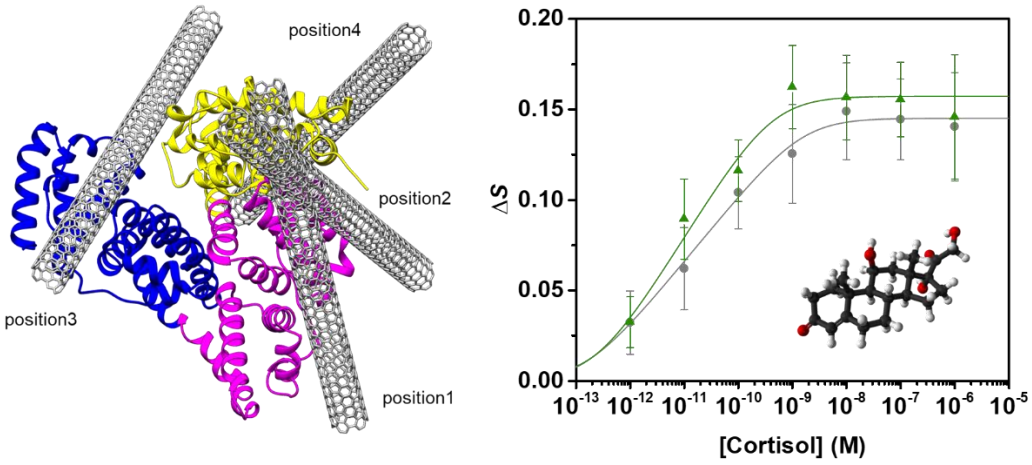
Carbon Nanotubes/Protein Hybrids for Healthcare Biosensing Applications

Alessandro Paradisi,[a] Marcello Berto,[a] Matteo Di Giosia,[b] Sara Mazzali,[a] Marco Borsari,[c] Tainah Dorina Marforio,[b] Francesco Zerbetto,[b] Matteo Calvaresi,[b] Anna Orieshyna,[d] Nadav Amdursky,[d] Carlo Augusto Bortolotti,[a] Fabio Biscarini[a,e]

[a] *Department of Life Sciences, University of Modena and Reggio Emilia, via Campi 103, 41125 Modena (Italy*
[b] *Chemistry Department "Giacomo Ciamician", Alma Mater Studiorum University of Bologna, Via Francesco Selmi 2, 40126 Bologna (Italy)*
[c] *Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Via Campi 103, 41125 Modena (Italy)*
[d] *Schulich Faculty of Chemistry, Technion–Israel Institute of Technology, 3200003 Haifa (Israel)*
[e] *Center for Translational Neurophysiology, Istituto Italiano di Tecnologia, Via Fossato di Mortara 17-19, 44121 Ferrara (Italy)*

alessandro.paradisi@unimore.it

Electrolyte-gated transistors (EGTs) are emerging as promising devices for biosensing in healthcare applications due to their unique ability to operate efficiently in aqueous environments and their high sensitivity allowing them to detect minute biological events, such as the binding of small molecules or proteins, with exceptional precision. These attributes make EGTs ideal for developing advanced, robust, and cost-effective biosensing platforms for medical diagnostics. In this context, semiconducting single walled carbon nanotubes (SWCNTs) are excellent semiconducting materials for EGT devices fabrication.[1,2] However, their primary drawback is the challenging solution processability required for EGT fabrication procedures, particularly when compared with alternative and widely exploited active materials in organic electronics, such as small molecules (e.g., pentacene) or polymers (especially PEDOT:PSS and P3HT). Here, we introduce a simple water-based approach that allows fabricating EGT devices from stable dispersions of SWCNTs/bovine serum albumin (BSA) hybrids in solution.[3] The deposition of this dispersion onto a suitable substrate forms a random network of SWCNTs, which serves as the semiconducting channel of the device. We demonstrate that this methodology allows the fabrication of EGT devices with electric performances suitable for biosensing applications. These devices are employed for the detection of target small molecules and proteins in solution, following gate electrode functionalization with the appropriate antibodies. This robust and cost-effective methodology sets the ground for a SWCNT/BSA-based biosensing platform that overcome many limitations of standard SWCNTs biosensor fabrication processes.



1. Molazemhosseini, A., Viola, F.A., Berger, F.J., Zorn, N.F., Zaumseil, J., and Caironi, M. (2021). A Rapidly Stabilizing Water-Gated Field-Effect Transistor Based on Printed Single-Walled Carbon Nanotubes for Biosensing Applications. *ACS Appl. Electron. Mater. 3*, 3106–3113.
2. Shkodra, B., Petrelli, M., Costa Angeli, M.A., Garoli, D., Nakatsuka, N., Lugli, P., and Petti, L. (2021). Electrolyte-gated carbon nanotube field-effect transistor-based biosensors: Principles and applications. *Appl. Phys. Rev. 8*, 041325.
3. Paradisi, A., Berto, M., Di Giosia, M., Mazzali, S., Borsari, M., Marforio, T.D., Zerbetto, F., Calvaresi, M., Orieshyna, A., Amdursky, N., et al. (2023). Robust Biosensor Based on Carbon Nanotubes/Protein Hybrid Electrolyte Gated Transistors. *Chem. Eur. J. 29*.