From Lab to Field: Integrating Graphene Biosensors into Autonomous Systems for Real-Time Environmental Monitoring

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In the realm of graphene-based biological sensors, their application spectrum has seen significant broadening, ranging from the realm of disease diagnostics to the detection of environmental contaminants. Yet, the practical deployment of SGFET technology in commercial settings has been very limited. Within the CEA-LETI, our perspective on these sensors transcends their standalone utility, advocating for their integration within comprehensive systems to achieve tangible field efficacy [1]. Our methodology encompasses the assimilation of these sensors into self-reliant systems able to perform fast, precise onsite monitoring of environmental parameters. This approach not only transcends the constraints of conventional laboratory techniques on which environmental analysis currently rely but also accentuates the necessity for holistic systems in realizing effective field deployment of micro- nano-biological sensors.

Through a strategic alliance with IFREMER (French national oceanography institute), we have been able to focus our effort on densely populated coastal regions susceptible to biological pollutants events. This partnership has been instrumental in pinpointing which critical biological pollutants to target and to each their optimal deployment conditions, as a specifications list for the design of the general systems that were assembled for graphene sensors on-field efficacy. Augmented by advanced data management and communication capabilities, the promise from the autonomous operation of these systems is to unlock effective real-time environmental surveillance, furnishing indispensable data for timely and informed decision-making processes by local authorities.

Through our inquiry, we underscored the paramount importance of sample preparation in augmenting the efficacy, versatility and reproducibility of graphene-based biosensors results in field scenarios. We have implemented custom innovative novel methodologies for the filtration, preconcentration, and buffer exchange, specifically tailored for the targeted biological species (bacteria, micro-algae, cyanobacteria, planktonic monocellular species) at hand. This endeavor is further enriched by our collaboration with Grapheal, leveraging their state-of-the-art, flexible graphene sensors. Our proprietary in-house biological functionalization technique, predicated on a non-covalent attachment mechanism, assures the biosensor specificity [2,3]. These technological advancements have facilitated pioneer initial field tests, with outcomes benchmarked against established methodologies.

In conclusion, we believe the transition of graphene-based biosensors into self-sufficient, field-ready systems heralds a new epoch in environmental monitoring. Gathering adequate data to fully understand the biological threats to coastal waters exacerbated by climate change remains a significant challenge. Both micro and nano biological sensors, especially graphene-based ones, have a crucial role to play in addressing this issue. In this talk, the authors will present several practical implementations of field-deployable biological sensors and the empirical results and teachings garnered over the past three years. We hope to shine a different light on practical applicability of biological sensors to enable label-free, on-field fast and precise measurements of biological targets of interest to the public.

Figure 1 : Composite illustration of the comprehensive process of deploying graphene-based biosensors for environmental monitoring. The wirelessly operated commercial grade SGFET developed by Grapheal. The state of the art non-covalent functionalization protocol we rely on to ensure specificity for the biosensor. Depicted on right hand is the deployment in a coastal setting, where autonomous vessels carry the biological analysis system that unlock effective real-time water analysis with graphene sensors.

References :
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