Description of my PhD project

The objectives of my project are to develop cost effective platform for scalable fabrication of biosensors with high specificity and sensitivity. For this purpose, Graphene based devices featuring a synthetic receptor for biomarkers recognition are microfabricated. This project is a collaboration between different departments and universities and I am working on the synthesis of the receptor.

Most commonly, biosensors are based on antibodies or enzymes, which are big biomolecules displaying a terrific selectivity for a targeted molecule. Unfortunately, these type of molecules are difficult to isolate or synthesize. The need of a new set of molecules that would be more easily accessible while still keeping the selectivity towards a target, paved the way for the development of synthetic receptors. We intend to synthesize our receptor by combining different types of triazole molecules to form differently 3D shaped trimers or tetramers. Triazole molecules can be easily and efficiently prepared with *click chemistry* [1], and they have a structure that imitates the peptidic bond (they are amidic bond isosters [2]) which indicates they could reach a good degree of selectivity.

Our aim is to finally functionalize graphene with this freshly synthesize receptor and obtain biosensors. These biosensors will be used as “plug-and-play” disposable chips with a micro-SD jack. We propose to develop miniaturized, low cost, rapid, highly sensitive and specific graphene-based sensors for detecting bacterial infections in the hospital settings. They will also be ready for incorporation into biomedical devices (e.g., catheters, implants), allowing their timely replacement in case of bacterial attachment.

Sustainability

The pursuit of cost-effective biosensors intersects with a fundamental tenet of sustainability: equity. This principle embodies the aspiration to afford every individual across the globe the opportunity to lead healthy and fulfilling lives. A critical axis in the production and deployment of biosensors revolves around the social dimension of sustainable development. This dimension gains heightened relevance as the World Health Organization (WHO) [1] recently flagged antibiotic resistance as a paramount threat to global health, food security, and developmental progress. The European landscape witnesses a staggering toll of approximately 25,000 annual deaths due to antibiotic-resistant infections, amounting to direct and indirect costs exceeding €1.5 billion. The shifting demographics and evolving lifestyles of the global population contribute to the emergence of conditions such as diabetes, venous hypertension, and compromised immune functions, elevating the risk of chronic, biofilm-associated infections.

My PhD project aims at to tackling this issue by developing rapid, robust, precise, and sustainable infection diagnostic kits using synthetic receptors on graphene.

One significant challenge faced by these devices is the lack of trust from society. This lack of trust affects both components of social dimension i.e., horizontal, and vertical relations. Addressing this challenge necessitates a socio-technical approach that harmonizes the interaction among diverse stakeholders. The main stakeholders in this approach would be 1) researchers enabling the technology, 2) civil society, 3) industries and 4) policy makers.

In my perspective, there's an imperative need to place a strong emphasis on the development of efficient technology demonstrating exceptional results in terms of sensitivity and selectivity in targeting diseases. While the primary focus leans towards technical solutions, a parallel consideration for altering societal perceptions through informational campaigns and strategic social marketing initiatives can complement these efforts. Communicated effectively and thoughtfully, technological advancements have the potential to influence behavioral shifts in society, triggering an alignment towards the acceptance of these advancements. This inclination, I believe, possesses the potential to emerge as a niche that could have far-reaching implications on the development and acceptance of these innovative sensors, impacting factors ranging from technological imperfections to societal behavior and networks.

The fate of synthetic recetors based biosensors is intricately entwined with the influence of socio-technical regimes, particularly the dominant companies steering the current diagnostic tool market. In the MLP framework, the concept of a regime is defined as: “the rule-set or grammar embedded in a complex of engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems all of them embedded in institutions and infrastructures” [6].

There's a potential conflict of interest for these significant companies, that are the key players within the socio-technical regimes. Introducing a cheaper alternative to existing diagnostic methods could significantly impact their revenues, possibly sparking resistance or hindrance. This resistance, despite the scientific evidence supporting the effectiveness of these biosensors, solidifies the existing socio-technical system's resistance to change. Moreover, societal shared beliefs and prevailing lifestyles might also act as barriers to the acceptance and integration of these innovative devices. The economies of scale and scope heavily favor the status quo, leaning towards the traditional diagnostic methods over the emerging graphene-based biosensors. This preference potentially triggers a lock-in mechanism, fortifying the position of established regimes and their traditional diagnostic approaches. To aid synthetic receptor-based biosensors in competing with these socio-technical regimes, a multi-level, dynamic strategy becomes imperative. Effectively communicating these results to civil society and policymakers could incite landscape-level changes and exert pressure on these entrenched regimes.

The other sustainable aspect of my project is to enhance cost-efficiency, to reduce the use of toxic solvents and reagents. This involves ecosystem sustainability and also tries to target an equity issue. To maintain fair distribution of these sensors worldwide especially in the under-developed and developing nations we try to run cost-effective reactions to synthesize the receptors for the biosensor. The special situation and needs of developing countries, particularly the least developed and those most vulnerable to harmful diseases, shall be given special priority.

Ethical Issue with Biosensors

From an anthropocentric ethical standpoint, biosensors hold pivotal value if we consider human well-being as the ultimate priority. While relatively new, biosensors play a crucial role in modern healthcare and disease control. Their swift response and technical superiority could significantly impact our healthcare system, but ethical concerns arise regarding equitable access to this technology, especially for poorer and developing nations. Historically, advanced technology, particularly in the medical field, tends to be more accessible for affluent and developed societies, creating a disparity.

In the conventional approach, biosensors are crafted on silicon wafers, relying on complex and hard-to-access biomolecules for target detection. This significantly affects the expenses, making these silicon-based biosensors out of reach for less economically privileged nations. This contradiction directly challenges the principles of hedonic utilitarianism, where human well-being stands as the paramount value. To address this challenge, our strategy involves not only leveraging cost-effective platforms—substituting silicon with plastics and making the receptor synthetically through easy procedures and accessible starting materials—but also embracing simplified manufacturing methods. This enables their creation in regions of necessity, particularly in the global south.

In connection with ecocentric ethics, we are trying to conduce organic synthesis by targeting the most common sustainability challenges in the field, like using hazardous reagents and solvents, which can pose risks to both human health and the environment. For instance, in the synthesis process, we are making efforts to use less harmful solvents by conducting reactions in water. While some reactions require metal catalysts, which can be expensive and not environmentally friendly, we are actively working on recycling these catalysts. This is feasible in our case, and we're also focused on minimizing the amount of metal catalyst used. Importantly, our reactions take place at room temperature, saving energy, and have short reaction times. While some reactions do produce CO2 as a side product, most of the reactions we're involved in either have no byproducts at all or produce byproducts that are water-soluble.

Role of a researcher

While biosensors exhibit efficiency in detecting diseases and harmful pathogens, further evidence collection is necessary to ensure their reliability and reproducibility. I believe that researchers and engineers will play a pivotal role in advancing this technology and ensuring its safe utilization. Applying an ethical framework to guide researchers working on biosensors involves considering the consequentialism theory. A cost-benefit analysis becomes crucial to understand the role and effectiveness of biosensors. The debate between the precautionary and proactionary principles also comes into play, deliberating whether to limit or encourage the impact of this new technology on people's lives. Personally, I advocate for the proactionary principle, believing that the positive impacts of biosensors will outweigh the negatives.

The intra-generational equity related to biosensors remains a point of observation. To address this, we emphasize the use of cost-effective platforms in biosensor manufacturing. Considering the broader societal effects of biosensors is also imperative. These sensors could reduce hospital or lab visits for diagnoses, enabling easy access for people to detect pathogens or viruses. However, the introduction of biosensors may impact privately operated hospitals and labs, reducing their regular visits (second-order effect). Additionally, this could influence the employment landscape in the diagnosis sector (third-order effect). Yet, the flourishing of biosensors relies significantly on intensive research to validate their efficacy for specific diseases or viruses. Here, the researcher's role in effectively communicating research outcomes becomes crucial.

The ethical code of the Swedish Association of Graduate Engineers, emphasizing the availability of expertise to inform decision-making and highlight technology's opportunities and risks, resonates with this scenario. Researchers in biosensor development should adopt the role of an impartial broker when presenting experimental evidence. Efforts should be made to engage policymakers and the public to communicate research outcomes effectively. Decisions regarding biosensor usage demand more than technical expertise and should involve consultation with various groups, including policymakers.

References

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