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September 14th, 2025

Dear adjudication committee for the *Geoffrey Ogram Memorial Research Grant,*

The Microfluidics and Nanotechnology (MiNa) laboratory at the University of Victoria is seeking $25,000 in funding to support the development of a saliva-based biosensor for simple, non-invasive, and accessible lung cancer screening.

Organized lung cancer screening programs in Canada have had a profound impact on the early detection of lung cancer, with each province working towards, or currently offering, full-fledged screening. Even though this transition will continue to be a powerful step forwards in battling lung cancer, we believe it can be taken even further.

Current screening relies on low-dose CT scanning, and as such, has relevant limitations. To avoid excessive radiation and overdiagnosis, there are restrictions placed on potential screening candidates and screening frequency. While these limits are likely beneficial for a wide array of individuals, they don't support those who develop cancer as a non-smoker, or those whose cancer advances at a rate faster than the screening period. As a result, we are working towards a potential screening technology that doesn't rely on CT scanning, hoping to increase screening availability, frequency, and accessibility for all.

Our proposed screening system is a biosensor specifically designed to selectively respond to lung cancer biomarkers in saliva, without the need for additional sample modification. The two biomarkers we are targeting have already proven relationship to lung cancer development and lung cancer stage, providing a non-invasive method for cancer detection and monitoring.

The MiNa lab team has historically challenged the development of sensing systems for analytes in complex environments, such as for the detection of both the *Cryptosporidium* pathogen and microplastic contaminants in water samples. Notably, the doctorate student who is spearheading this project is experienced in sensor development for biomarker detection, with previous work in the fields of glucose monitoring and early prostate cancer detection.

As this project is currently unfunded, any monetary contributions to this research will be used to purchase research materials for sensor development and testing, rent equipment time for sensor characterization, and support our doctorate student.

Thank you for the opportunity to submit this proposal. Should you have any questions or would like additional information, please don't hesitate to contact me using the details below.

Yours truly,

Mina Hoorfar, PhD, PEng, FCSME, FCSSE, FCAE
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Summary of Proposed Research

Introduction

For diseases such as lung cancer, an early diagnosis greatly impacts the likelihood of successful treatment. Although Canada is actively working to support early diagnosis through low-dose CT-based cancer screening, there are many limitations with the current programs. Not only does access to organized screening vary provincially, but screening is also only performed annually, and on individuals with significant risk factors.

These limitations, while necessary to avoid factors such as overdiagnosis and unnecessary radiation exposure, leave many susceptible to undetected cancer progression. Even with organized CT-based lung cancer screening, 30-40% of cases are diagnosed when they are already at stage III or IV – resulting in a 5-year survival rate below 20% and below 5%, respectively [1]. This may be impacted by the fact that just under 30% of lung cancer cases occur in non-smokers, who are often not eligible for organized screening [2]. Additionally, lung cancer screening has historically had low participation rates, with the Canadian Cancer Society estimating a 40% participation rate in screening simulations [3]. Research has also shown that the rate of lung cancer progression varies heavily between individuals and that it can take less than one year for a small lung lesion to progress into advanced stage lung cancer, suggesting that annual screening may not be suitable for everyone [4]. These statistics highlight Canada's need for alternative systems that can safely facilitate lung cancer screening for a broader population, at a narrower testing frequency, and with reduced risk for radiation exposure and overdiagnosis.

Background & Objective

As medical technology continues to improve, screening procedures that analyze easily accessible biofluids are becoming the standard. For example, both cervical and colorectal cancer screenings can be done through non-invasive, at-home tests, which are both physically harmless and have shown to increase screening participation rates [5], [6], [7]. Among all bodily fluids, saliva – ideal for analysis due to its non-invasive and simple collection procedures – contains the second-highest number of distinct microRNAs (miRNAs), a useful class of biomarker for cancer detection [8], [9].

During cancer progression, certain miRNAs become dysregulated due to their role in either tumour suppression or growth, which impacts their concentrations in various bodily fluids [10], [11], [12]. Many research groups are further analyzing the relationship between different miRNAs and lung cancer, with miRNA-141 and miRNA-21 proving to be particularly intriguing [13]. In one study, the level of miRNA-141 in plasma was found to have a 98% specificity in recognizing early non-small cell lung cancer (NSCLC) and miRNA-21 was found to be positively correlated with cancer stage [14]. This suggests that these two biomarkers could be used in tandem to not only identify NSCLC early on, but also effectively monitor its progression or regression over time. Additionally, miRNA-21 and miRNA-141 have proven ability to be identified within and extracted from saliva, making them excellent candidates for saliva-based screening [15], [16].

Due to the extremely low concentration of miRNA in biofluids (roughly a billion times lower than the concentration of glucose in the bloodstream [17]), a technique called *polymerase chain reaction* is often used to amplify the miRNA to detectable levels, requiring trained technicians,

expensive materials, and multiple hours of time [18]. Our objective is to create an electrochemical biosensor with a high enough sensitivity towards miRNA-21 and miRNA-141 to recognize and monitor lung cancer through saliva samples directly, without the need for miRNA amplification techniques, offering a non-invasive and less resource-intensive screening method.

Methodology

Electrochemical-based sensing has become a staple sensing methodology for miRNA bio-detection due to its affordability, adaptability, and ease of enhancement and use [19]. While it primarily holds popularity for detection within blood serum or plasma, researchers have found that saliva-based detection may be equally as favourable due to comparable miRNA concentrations [20].

Current Progress

The detection of biomolecules like miRNA, due to their traditionally weak conductivities and low concentrations, often benefits from the incorporation of capture probes on the sensor surface – small RNA or DNA sequences that perfectly bind with their corresponding miRNA [21]. Based on this, initial research to-date (led by PhD student, Abbas, experienced in analytical chemistry and miRNA sensor development [22]) has focused on increasing the sensitivity of the sensor, achieved by boosting the potential current density and maximizing the surface area of the sensing surface, as well as generating a co-polymer layer that will readily accept miRNA-21 and miRNA-141 capture probes (see Appendix, Fig. 1). Preliminary results, using a combination of nitrogen-doped graphene and a copolymer made of poly(aniline) (PANi) and poly(4-aminobenzoic acid) (P4ABA) appear promising (see Appendix, Fig. 2). The graphene and PANi contribute to the sensitivity of the sensor due to their high conductivities and surface areas, whereas the P4ABA assists with selectivity, as it has the ideal functional groups to bind with the capture probes.

Upcoming Research

Future work will target the incorporation of miRNA capture probes on the polymer surface (in the form of specifically-designed single-stranded DNA), as well as the addition of metals into the copolymer backbone to make a metal-copolymer hybrid (see Appendix, Fig. 3) – a class of material that has proven significant efficacy in the biomarker detection realm with respect to sensitivity [23]. The sensor will continue to be characterized by various electrochemical techniques, such as cyclic voltammetry and differential pulse voltammetry, amongst others, and analyzed through standard methods such as scanning electron microscopy and x-ray diffraction, expected to take ~6 months. In-lab testing and optimization will follow, using synthetic saliva spiked with miRNAs to replicate the salivary environment noted in those with lung cancer.

Expected Outcomes and Impact

While we expect the formulation for a saliva-based lung cancer sensor to be the direct outcome of this research, the *Geoffrey Ogram Memorial Research Grant* will directly support the translation of this work from materials-based sensor design into near-true biological validation, a critical shift in moving towards simple and accurate on-site screening for lung cancer. Through this, we aim to work towards a reality where lung cancer screening is more accessible, offering opportunities for higher testing frequencies, broader testing participation, and less overall risk – identifying lung cancer at its earliest stages.

Appendix

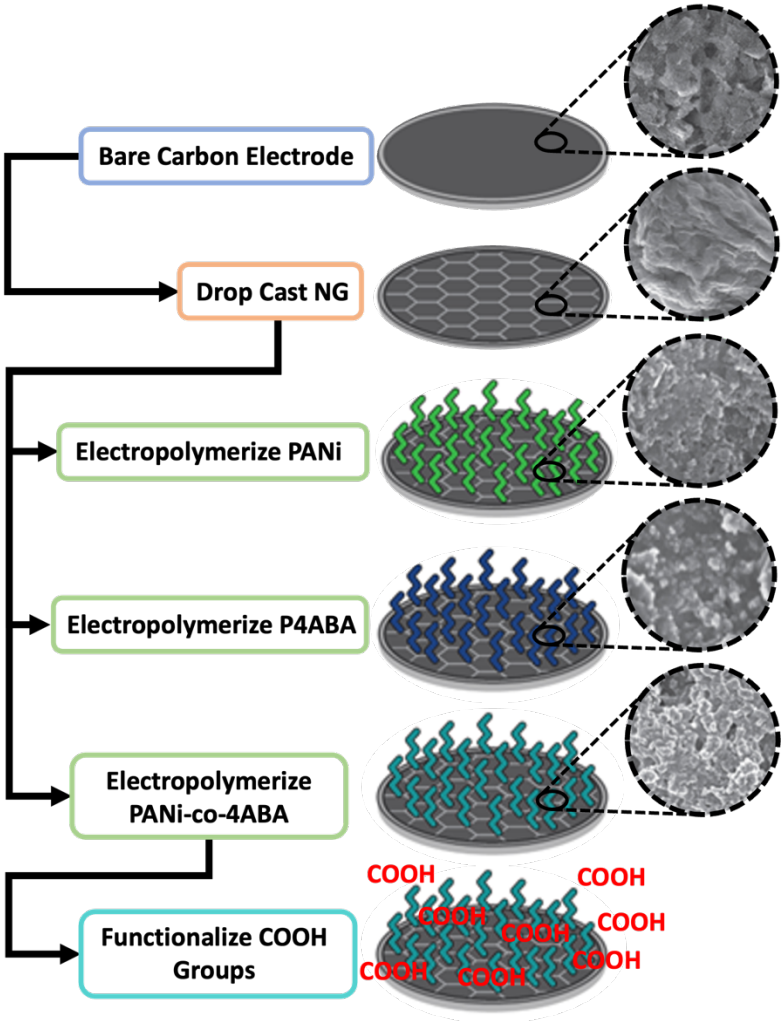

Figure 1. Initial layer modifications to a bare carbon electrode, with schematic representation on the left and scanning electron microscopy images on the right, where NG refers to nitrogen-doped graphene, PANi refers to poly(aniline), P4ABA refers to poly(4-aminobenzoic acid), PANi-co-4ABA refers to a copolymer consisting of PANi and P4ABA, and COOH refers to carboxyl groups – an important feature for binding to miRNA capture probes.

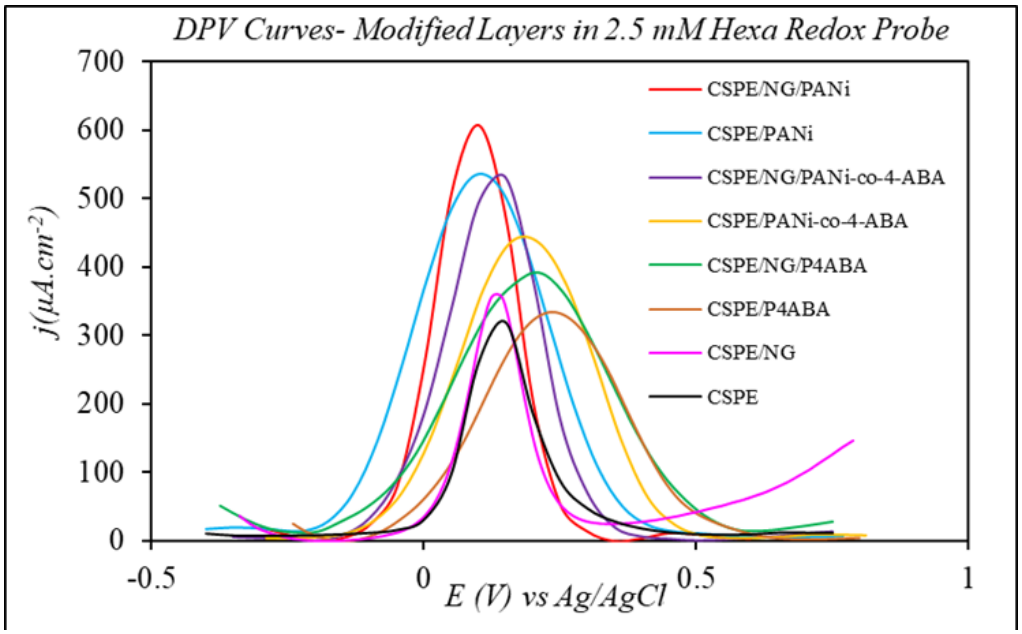

Figure 2. Differential pulse voltammetry (DPV) curves for different layer modification combinations, highlighting the change in current density (*j*) with each material, where CSPE refers to a bare carbon screen printed electrode, NG refers to nitrogen-doped graphene, PANi refers to poly(aniline), P4ABA refers to poly(4-aminobenzoic acid), PANi-co-4-ABA refers to a copolymer consisting of PANi and P4ABA.

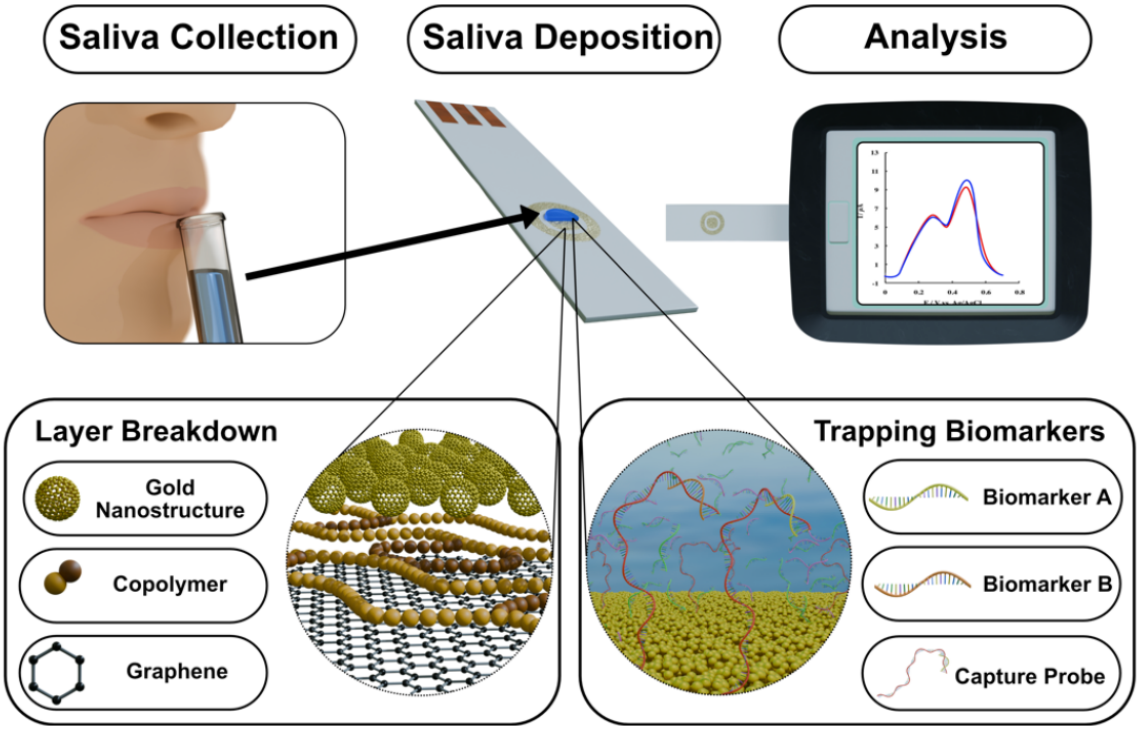

Figure 3. Proposed finalized sensor design and use case for saliva-based lung cancer detection.

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Impact Statement
The development of a saliva-based biosensor for lung cancer detection will offer simple, non-invasive, and accessible lung cancer screening - allowing for a wider screening pool and more frequent testing. This will permit the detection of lung cancer cases that would have been missed within traditional screening limitations and will support the possibility for earlier medical intervention, providing the greatest opportunity for improved patient outcome.

Public Summary
Canada's efforts to increase the availability of lung cancer screening has been incredibly successful, with all provinces either moving towards, or offering, organized lung cancer screening programs. These programs are an important step towards facilitating the early detection of lung cancer, however, as screening currently relies on radiation-based imaging, there are many restrictions regarding who is eligible for screening and how often screening can occur. With these limitations in place, not all lung cancer cases will be caught in time for effective treatment, especially for those who develop cancer as a non-smoker or who have a particularly fast-growing cancer. To combat this issue, we are working on an alternative lung cancer screening system that doesn't rely on radiation, is non-invasive, and is simple to use, with the hopes of being able to screen more people, more often.

Lung cancer starts when healthy lung cells experience a series of genetic mutations, causing them to shift into abnormal cells that grow uncontrollably. Both healthy and cancerous cells will occasionally expel some of this genetic information out of the cell as part of normal cell behaviour, resulting in pieces of this genetic information ending up in various bodily fluids – including blood and saliva. Due to the mutations in the cancer cells, these microscopic bits of information will differ from healthy cells, just like how cancerous lung tissue appears different from healthy lung tissue on a radiation-based scan. Our goal is to make a sensor that can recognize these tiny bits of genetic information within saliva to identify signs of lung cancer without needing to see it.

A sensor has two primary characteristics – its sensitivity, e.g., *"how small of a concentration can it detect?"*, and its selectivity, e.g., *"how precisely does it respond to the target without being impacted by nearby compounds?"*. In a complex fluid like saliva that experiences constant change as we eat or drink, having a sensor that is both incredibly sensitive and selective is of extreme importance, especially for biomarkers with very small concentrations. We are accounting for these needs by incorporating a variety of unique materials into a saliva-compatible sensor to significantly boost its sensitivity, allowing it to detect extremely low concentrations. In addition, we are adding specialized elements to the top of the sensor surface so that it will only respond to the lung cancer-specific compounds in saliva, making sure that other components don't impact the sensor.

With this work, we hope to move towards the potential of saliva-based lung cancer screening, offering a screening system that is simple, non-invasive, and has no risks associated with radiation exposure. By facilitating this type of screening, we aim to encourage broader screening participation and narrower testing frequencies, with the goal of recognizing lung cancer earlier and offering the best opportunity for recovery.

Budget Justification

The total proposed budget for this project is $25,000, 60% of which is dedicated to student support, 20% to necessary research materials, and 20% to cover various characterization equipment usage fees.

1. **Student Support**
   A budget of $15,000 is allocated to supplement financial support for one doctoral (PhD) student (Abbas Sabahi), with the remaining student support being funded by an NSERC Discovery Grant. The PhD student has a strong background in biosensor development, having worked on electrochemical-based sensors for both glucose monitoring in blood and the detection of prostate cancer using serum samples. The student's work on prostate cancer detection also focused on microRNA-based detection, proving his capabilities to develop and optimize sensors for microRNA specific capture and response. The development of this miRNA-based sensor for lung cancer detection is the focus of the student's thesis, indicating their fulltime commitment to the project.

2. **Materials**
   A total budget of $5,000 is allocated towards material costs which will go towards the purchasing of electrodes, chemicals required for the modification of the sensing layer (e.g., doped graphene, compatible forms of gold, capture probes), and chemicals required to assess the sensor, such as those used to make artificial saliva solution. It will also go towards the purchase of specialized labware, such as a Liebig condenser (~$200), that will be required for various chemical processes.

3. **Equipment Usage**
4. A total budget of $5,000 is allocated towards user fees for various material characterization equipment, including scanning electron microscopes, Raman spectroscopy systems, Fourier-transform infrared spectroscopy systems, and x-ray diffraction machines. At the University of Victoria, the user fees for these machines are on average $70/hour but may increase upon the need for specific training or required surface treatments before use. We are allotting roughly 60 hours of equipment usage, including leeway for special cases where additional training or treatments are required.

Investigators

- ***Primary Investigator:*** Mina Hoorfar
    - **Student Investigator:** Abbas Sabahi

Date: 25 September 2025

Lung Cancer Canada
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Toronto, ON
M5H 2L3

Dear Geoffrey Ogram Memorial Research Grant review committee,

On behalf of the University of Victoria, I am pleased to provide this letter of support for Dr. Mina Hoorfar's application entitled "Saliva-based Lung Cancer Detection for Simple, Non-invasive, and Accessible Lung Cancer Screening". Upon successful completion of the project, the team will have completed preliminary research towards the development of an electrochemical-based biosensor for lung cancer detection through saliva samples, opening pathways regarding the possibility of simple and non-invasive lung cancer screening.

I confirm that the proposed research is feasible to conduct here at the University of Victoria.

In the *Microfluidics and Nanotechnology Lab*, the *Brolo Lab*, and the *Centre for Advanced Materials and Related Technology* at the University of Victoria, the investigators have access to resources and equipment that are necessary to carry out this project, such as a scanning electron microscope, a Raman spectroscopy system, an x-ray diffractometer, a Fourier-transform infrared spectroscopy system, and a potentiostat.

We look forward to a successful outcome.

Sincerely,

Dr. Brad Buckham
Professor & Chair
Department of Mechanical Engineering
Faculty of Engineering & Computer Science
University of Victoria