Detection of HIV in Clinical Plasma Samples via a Custom-Built Surface Plasmon Resonance Using an Anti-HIV-gp120 Monoclonal Antibody

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Presentation outline

- About the CSIR
- Introduction
- Methodology
- Results and discussion
- Future work and conclusion
- SPR adoption in South Africa: Challenges and solutions
- Acknowledgements

CSIR mandate

"The objects of the CSIR are, through **directed** and **particularly multidisciplinary research** and **technological innovation**, to foster, in the **national interest** and in fields which in its opinion should receive preference, **industrial** and **scientific development**, either by itself or in **co-operation with principals** from the **private** or **public sectors**, and thereby to contribute to the **improvement of the quality of life** of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act."

Scientific Research Council Act, 1988
(Act 46 of 1988, amended by Act 27 of 2014)

Our mandate is to conduct multidisciplinary research and innovation to improve the quality of life of the people of South Africa through collaboration with private and public sectors.

CSIR Operating Model

INDUSTRY ADVANCEMENT CLUSTERS

Advanced Agriculture and Food

Strengthen primary production through precision agriculture and develop value added products and processes for sector competitiveness

Future Production: Chemicals

Advanced materials, product and process development for pharmaceuticals, chemical and allied industries

NextGen Health

Develop technologies, products and processes that contribute to the reduction of burden of disease and enhances pandemic preparedness

Future Production: Manufacturing

Strengthen the manufacturing value chain to enhance industry competitiveness

Future Production: Mining

Support the growth and revitalisation of the mining industry

Defence and Security

Build resilient defence and security capabilities to strengthen national security

DIVISIONS

- Advanced Chemistry and Life Sciences
- Advanced Production and Security

INDUSTRY & SOCIETY-ENABLING CLUSTERS

Smart Places

Enable smarter natural resource use, environmental sustainability and smart infrastructure

Smart Mobility

Enable South Africa to have an efficient, effective, integrated, safe and competitive Transport and Logistics sector

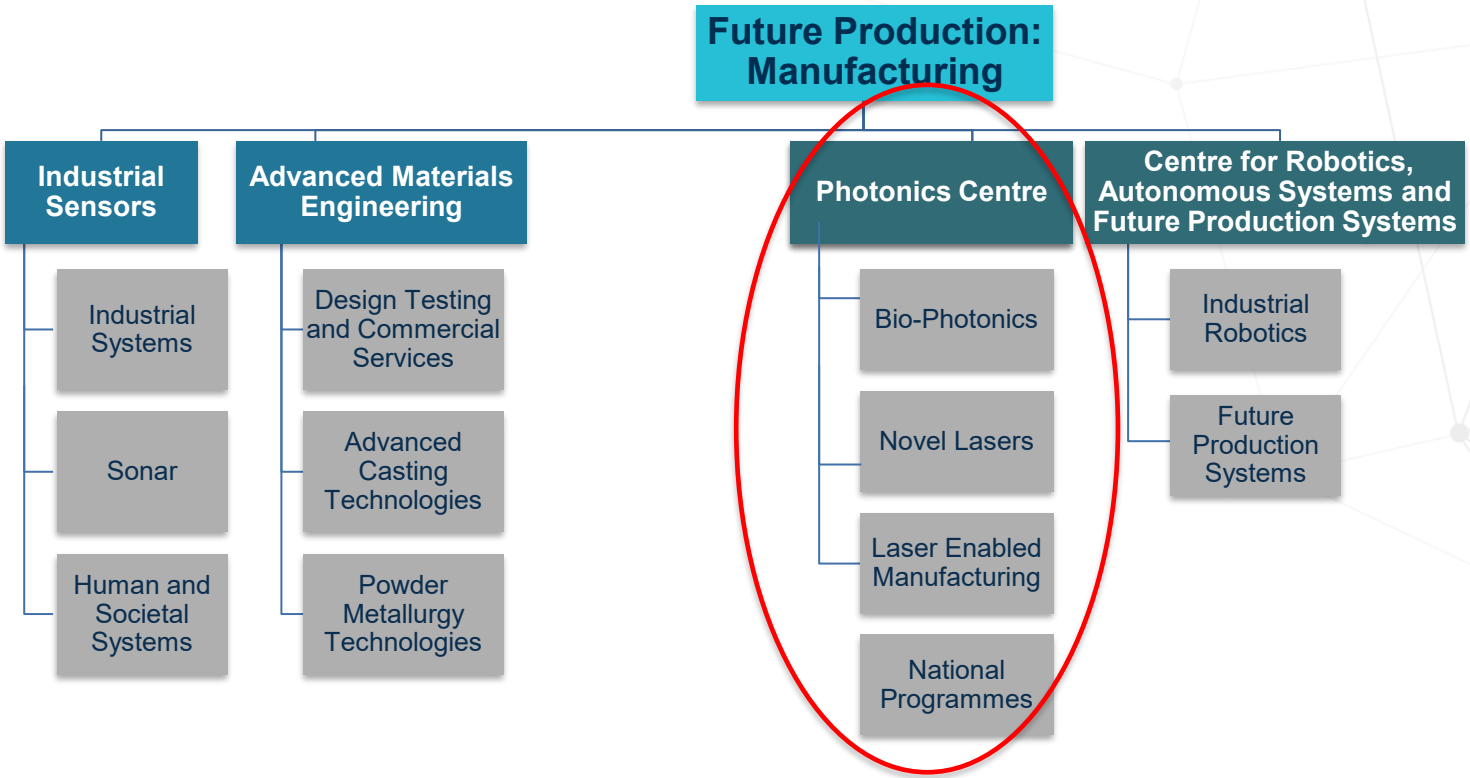
NextGen Enterprises and Institutions

Enable digital transformation in government, public institutions and industry

DIVISIONS

- Smart Society

Manufacturing cluster structure



The Biophotonics research group is focusing on investigating and developing photonics-based tools for the detection of diseases as well as screening medicinal products to identify counterfeits and substandard ones.

Why detect HIV? Introduction

WHY DETECT HIV & MEASURE VIRAL LOAD USING SPR IN SOUTH AFRICA

Fast. Sensitive. Real-time. For better HIV care and a healthier future.

1. HIGH HIV BURDEN

South Africa has one of the largest HIV epidemics globally.

~7.8 MILLION
people living with HIV (2022)

Large-scale testing and monitoring systems are essential to manage treatment and reduce transmission.

2. VIRAL LOAD IS CRITICAL

Viral load (VL) is the gold standard for monitoring treatment.

- ✓ Shows if treatment is working
- ✓ Detects treatment failure or drug resistance
- ✓ Supports adherence monitoring

Achieving viral suppression improves health and prevents HIV transmission.

3. NEED FOR FASTER, REAL-TIME DIAGNOSTICS

Conventional viral load testing is centralized and time-consuming.

↓

Delays in diagnosis and treatment initiation

SPR provides rapid, real-time results for immediate clinical decision-making.

4. DECENTRALIZATION & RURAL ACCESS

Many patients access care in primary healthcare clinics and rural areas.

SPR enables point-of-care testing, bringing diagnostics closer to patients and improving access.

5. ADVANTAGES OF SPR FOR HIV DETECTION

- Label-free detection (No complex reagents)
- Real-time monitoring of biomolecular interactions
- High sensitivity for low viral concentrations

Enables early and accurate detection with high reliability.

6. SUPPORTS NATIONAL HIV GOALS

South Africa aims to meet UNAIDS 95-95-95 targets:

95%	95%	95%
Diagnosed	On Treatment	Virally Suppressed

Viral load monitoring is essential to achieve these targets and control the epidemic.

OUR GOAL

Develop SPR-based biosensors for rapid, accurate and real-time HIV detection and viral load monitoring to improve care, save lives and help end the HIV epidemic in South Africa.

THE IMPACT

- Faster Results
- Early Detection
- Better Monitoring
- Improved Outcomes
- Stronger Epidemic Control

SPR brings innovation to South Africa's healthcare system—delivering fast, sensitive and accessible diagnostics for a healthier future.

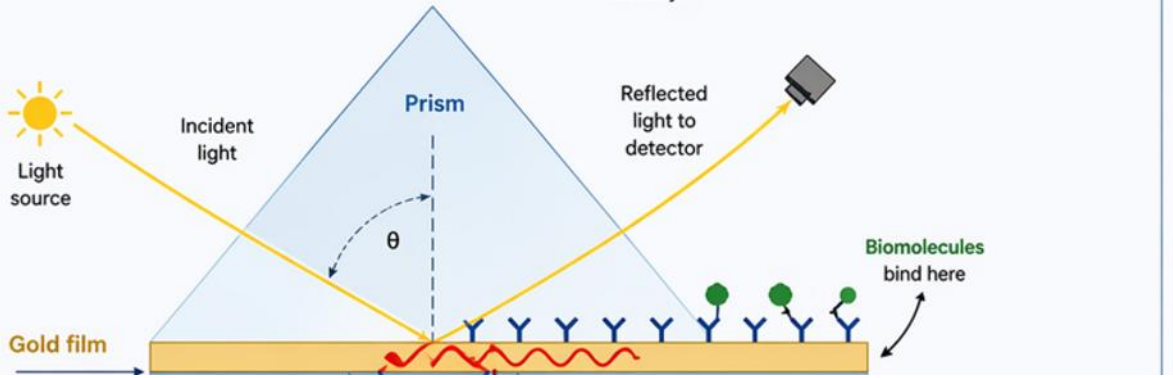
Introduction cont’

SURFACE PLASMON RESONANCE (SPR) PRINCIPLE

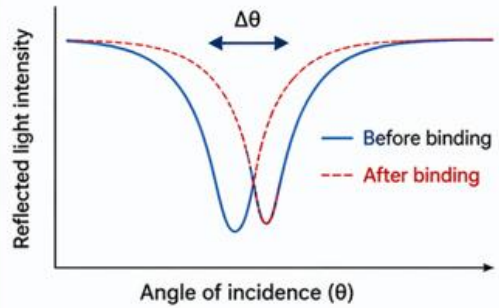
SPR detects biomolecular binding events by measuring changes in refractive index near a metal surface using light.

HOW SPR WORKS

1. Polarized light is directed through a prism onto a thin gold film.
2. At a specific angle, light undergoes total internal reflection, creating an evanescent field.
3. The evanescent field excites surface plasmons (electron oscillations) in the gold film.
4. At resonance, energy is transferred from light to electrons, causing a sharp dip in reflected light intensity.
5. When biomolecules bind to the surface, the local refractive index changes.
6. This shifts the resonance angle or intensity, which is detected in real time.



SPR SIGNAL



Binding of biomolecules → Refractive index ↑ → Resonance angle shifts (Δθ)

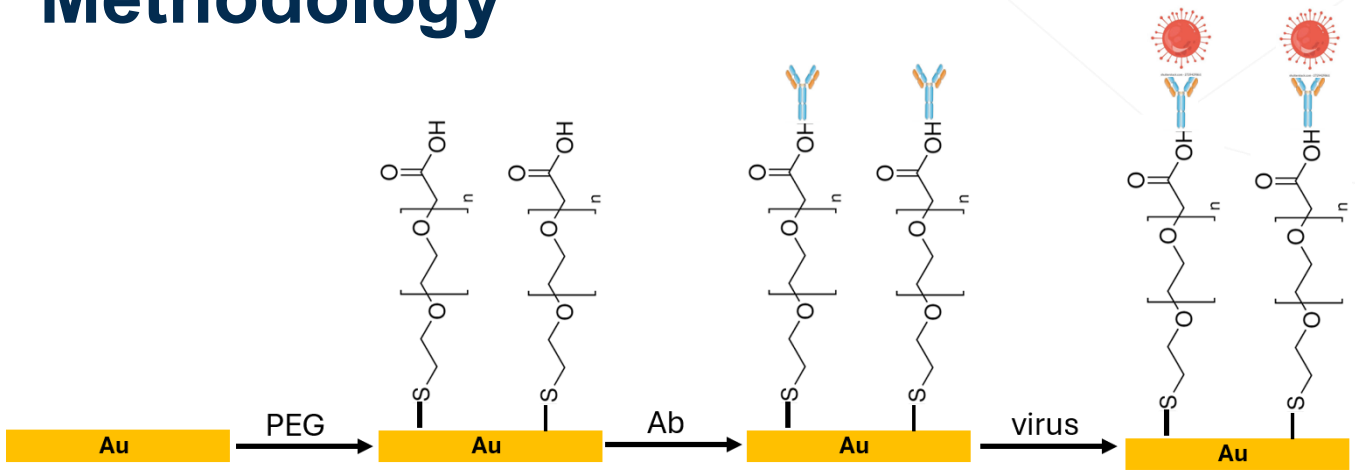
KEY POINTS

- SPR occurs when light couples with electron oscillations on a metal surface.
- The resonance is sensitive to changes in the refractive index near the surface.
- SPR enables label-free, real-time detection of biomolecular interactions.
- The magnitude of the shift is proportional to the amount of material bound.

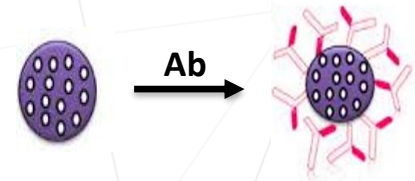
Aim

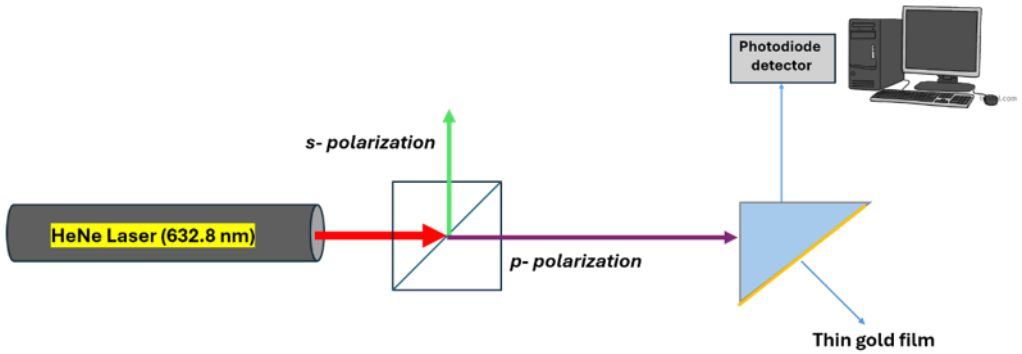
To evaluate a custom-built SPR biosensor for label-free qualitative detection of HIV in clinical plasma samples.

Methodology

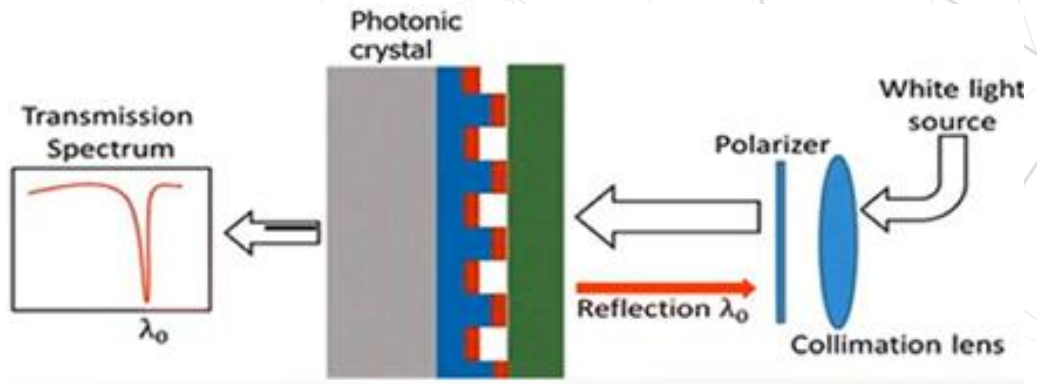


A schematic representation of the chip and sample preparation (gold coated slide or photonic crystal)





A simplified diagram of surface plasmon resonance



A schematic representation of a photonic crystal biosensing system

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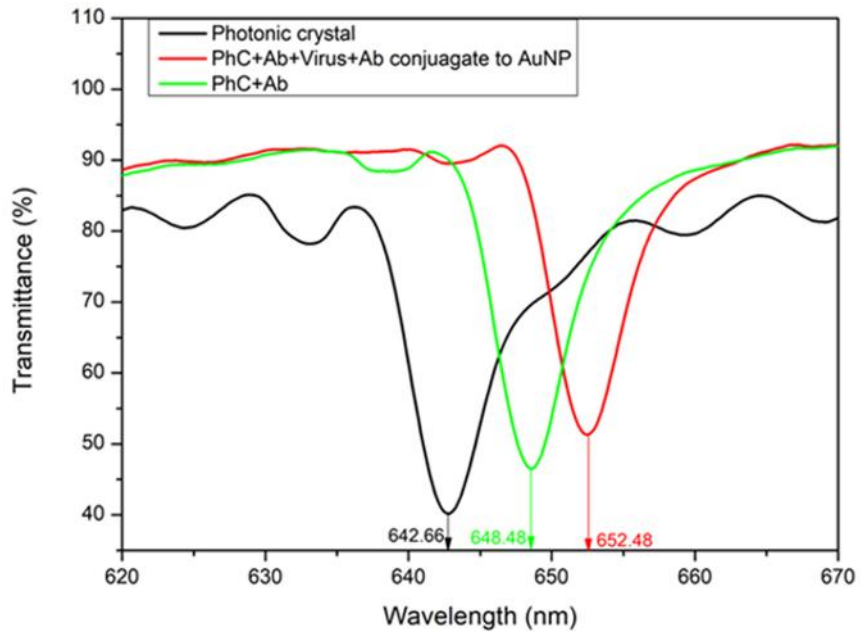
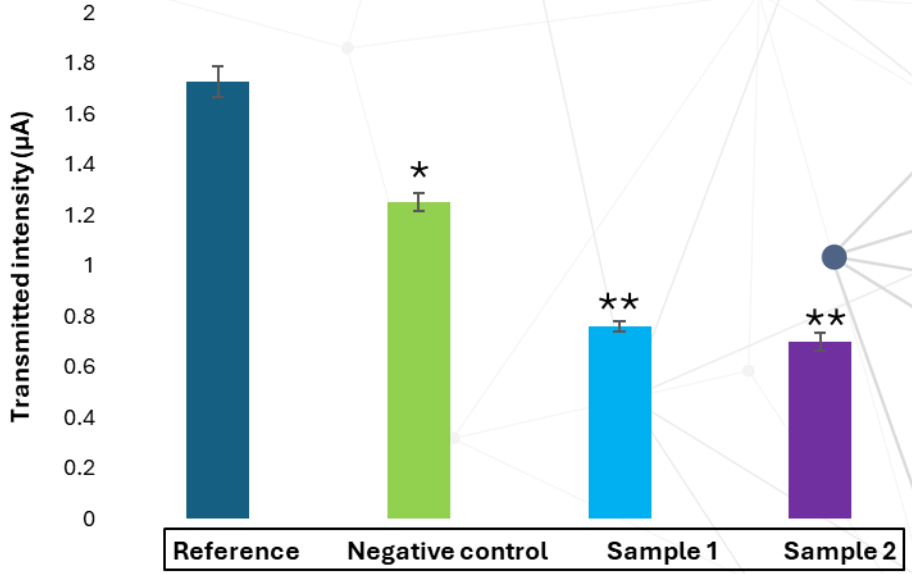
Results and Discussion:
HIV detection on gold coated surface and photonic crystal





Results showing wavelength shift when detecting HIV (pseudovirus) on a photonic crystal and measuring transmittance intensity of gold coated surface

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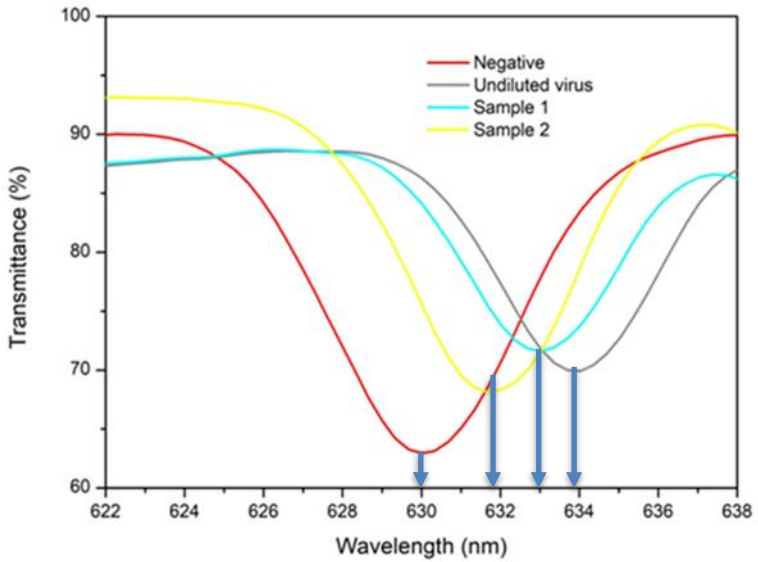
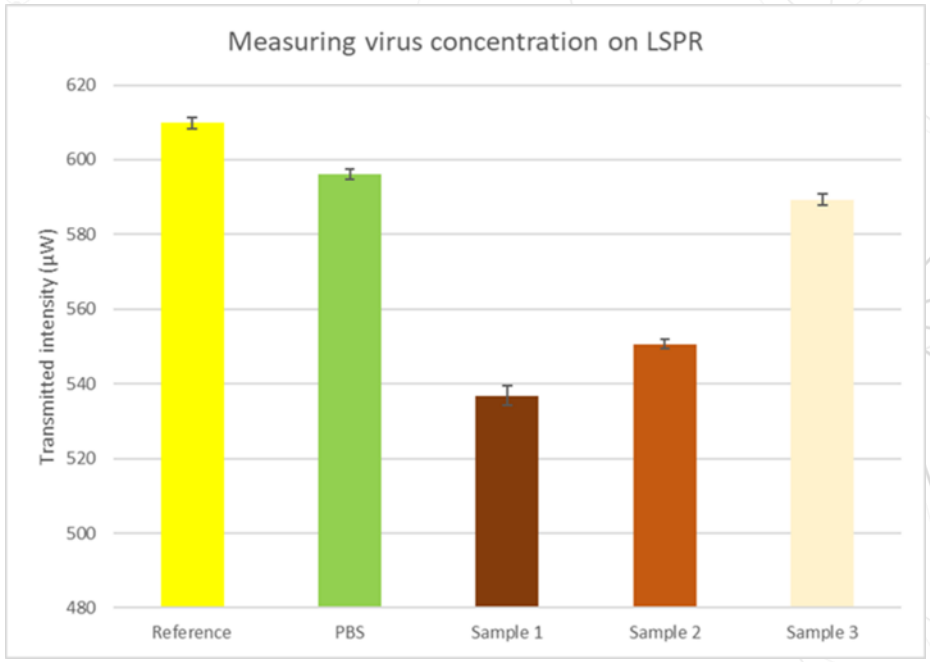
Results and Discussion:
HIV quantification on gold coated slides and photonic crystals





Results showing wavelength shift when quantifying HIV (pseudovirus) on a photonic crystal and measuring transmittance intensity of gold coated surface

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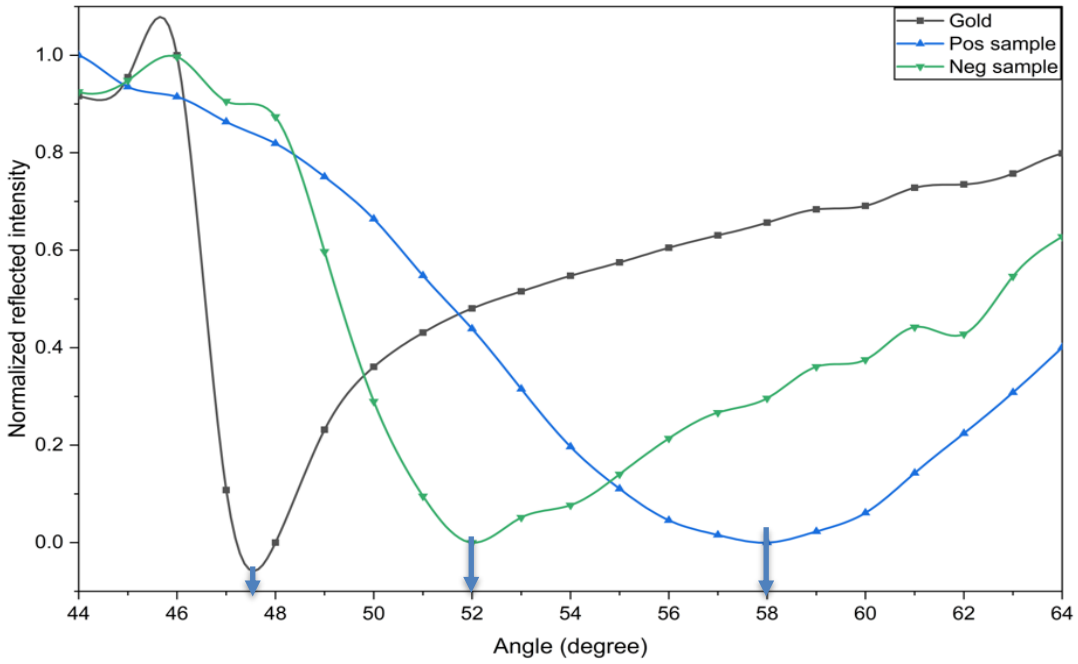
Results and Discussion



Results showing angle shift when detecting HIV from clinical samples on gold coated surface

- The resonance angle of bare gold coated sensor chip was 47.5° with a sharp decrease in reflectivity which is a typical response of a clean gold film and a homogeneous dielectric environment.
- The functionalized chip with a Neg sample exhibited a right shift to 52° indicating higher refractive index compared to the gold and a less homogenous dielectric environment due to sample complexities (hence the broad curve).
- Pos sample demonstrated a further right shift to 58° which is indicates a significant refractive index increase due to the viral gp120 binding to the antibody as well as the presence of other viral and sample components.

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Future work and conclusion

Conclusions

- Clear differences between HIV-positive and HIV-negative samples.
- The findings support the feasibility of developing the SPR biosensor into a device capable of HIV detection, viral load monitoring and identification of HIV drug-resistance mutations.
-

Future work:

- Assessment sensitivity, specificity, limit of detection, reproducibility, reduce unspecific binding observed in the negative sample.

SPR ADOPTION IN SOUTH AFRICA: CHALLENGES & SOLUTIONS

Enabling Surface Plasmon Resonance for Better HIV Diagnostics and Monitoring

CHALLENGES	SOLUTIONS / MITIGATION STRATEGIES	IMPACT
1 **INFRASTRUCTURE & SYSTEM INTEGRATION** — Difficulty integrating SPR into existing lab-based workflows.	• Develop hybrid diagnostic models (SPR for screening + PCR for confirmation). • Align SPR with national HIV diagnostic algorithms.	Seamless integration into national HIV testing pathways and better continuity of care.
2 **COST AND RESOURCE CONSTRAINTS** — High initial device and deployment costs.	• Focus on low-cost, miniaturized SPR platforms. • Local manufacturing and partnerships. • Demonstrate cost-effectiveness vs central PCR.	Affordable, sustainable solutions for public health and wider access.
3 **LIMITED TRAINED PERSONNEL** — Poor adoption in rural/primary care settings.	• Implement training programs for nurses and technicians. • Use user-friendly, automated SPR systems. • Enable task-shifting to community health workers.	Skilled workforce and broader adoption at PHC and community level.
4 **LACK OF CLINICAL VALIDATION** — Delays in regulatory approval and clinical uptake.	• Conduct clinical trials with local patient samples. • Align with SAHPRA and WHO validation frameworks. • Publish performance benchmarks vs PCR.	Regulatory approval and greater confidence in clinical performance.
5 **SUPPLY CHAIN AND MAINTENANCE** — Device downtime and inconsistent service delivery.	• Develop robust supply chains for consumables. • Create local service and maintenance hubs. • Use durable, field-ready device designs.	Reliable, continuous service delivery across diverse settings.
6 **WEAK DIGITAL INFRASTRUCTURE** — Poor data sharing and patient monitoring.	• Integrate SPR with mobile health (mHealth) platforms. • Enable smartphone-based readouts and cloud data storage.	Real-time data connectivity, monitoring and surveillance improvements.
7 **ADOPTION RESISTANCE** — Slow uptake into routine healthcare (policy & clinicians).	• Engage stakeholders early (clinicians, policymakers). • Demonstrate clinical utility and workflow benefits. • Pilot studies in PHC clinics.	Stronger stakeholder buy-in and faster scaling of SPR technologies.
8 **RURAL ACCESS CHALLENGES** — Limited reach of advanced diagnostics.	• Deploy SPR in portable, point-of-care formats. • Integrate into mobile clinics and outreach programs.	Improved access to diagnostics in rural and underserved areas.

THE GOAL

Decentralized, affordable, and reliable SPR-based diagnostics integrated into South Africa's health system.

BENEFITS

- Faster results
- Early detection
- Better monitoring
- Improved treatment outcomes
- Stronger epidemic control

Towards ending HIV in South Africa

KEY ENABLERS FOR SUCCESS

- Strong partnerships (academia, govt, industry, communities)
- Adequate funding and sustainable financing
- Supportive policies and regulatory frameworks
- Local innovation and manufacturing capacity
- Continuous quality assurance and monitoring

TAKE-HOME MESSAGE

Addressing these challenges with targeted strategies will enable SPR technology to transform HIV diagnostics and monitoring across South Africa.

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NRF National Research Foundation

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Thank you!