Silver nanowire thin-film heaters in bioplastic microfluidic devices for molecular diagnostics

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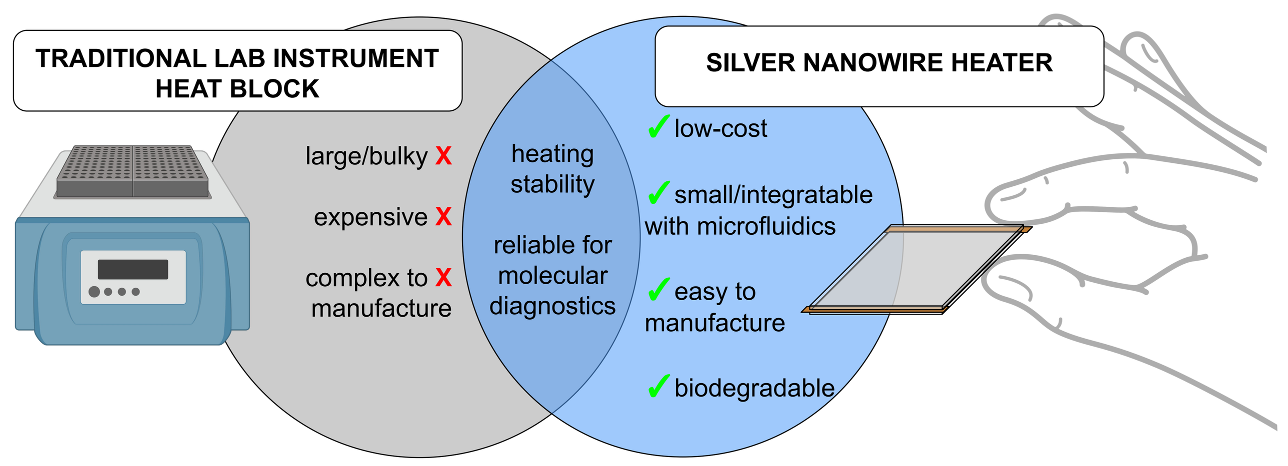
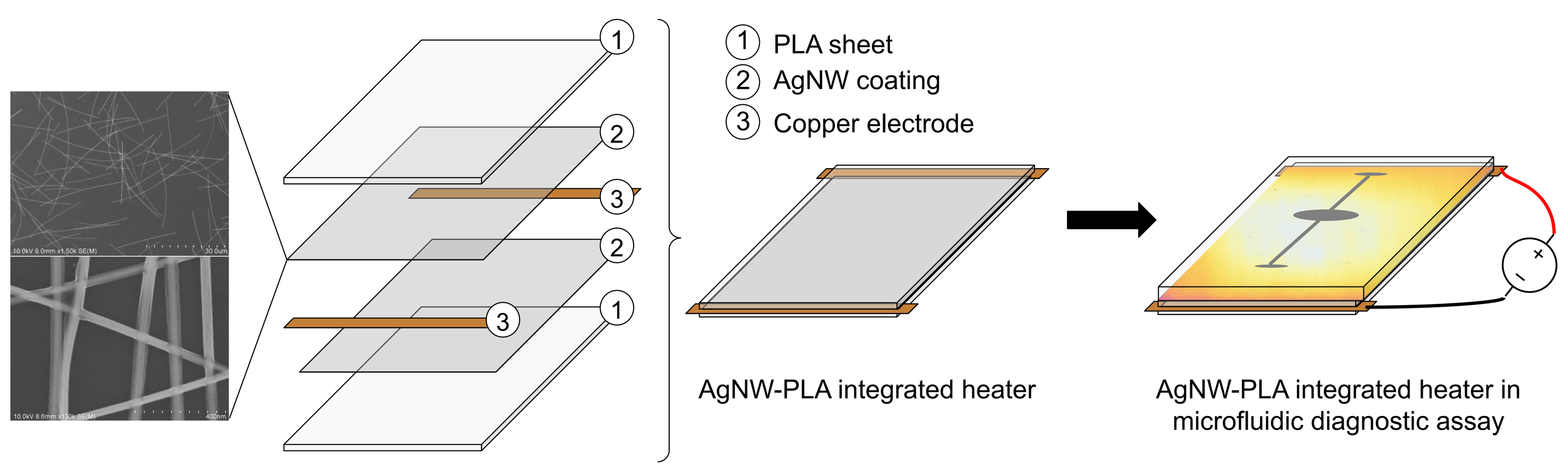
Introduction

- Microfluidic nucleic acid detection assays rely on **bulky**, **expensive** laboratory equipment, limiting their application in **point-of-care** settings
- Aim to develop a **low-cost**, **minimal-equipment** heating method using **transparent**, **conductive** silver nanowires on microfluidic devices
- Great potential for more **sustainable** and **accessible** health monitoring

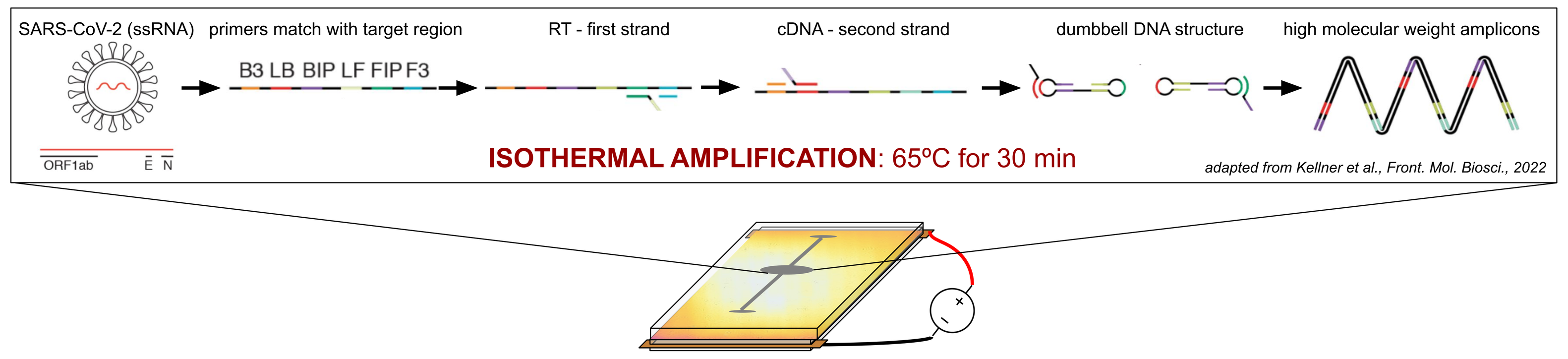


Method

- Custom fabrication technique developed to integrate silver nanowires (AgNW) and bioplastic polylactic acid (PLA) for thin-film, transparent heater



- Heating ability characterized with Arduino-powered thermocouples & Seek infrared thermal camera
- Demonstration of molecular diagnostic assay on a microfluidic chip: isothermal amplification with AgNW-PLA heater via RT-LAMP for detection of SARS-CoV-2 in saliva



Results

Heating characterization

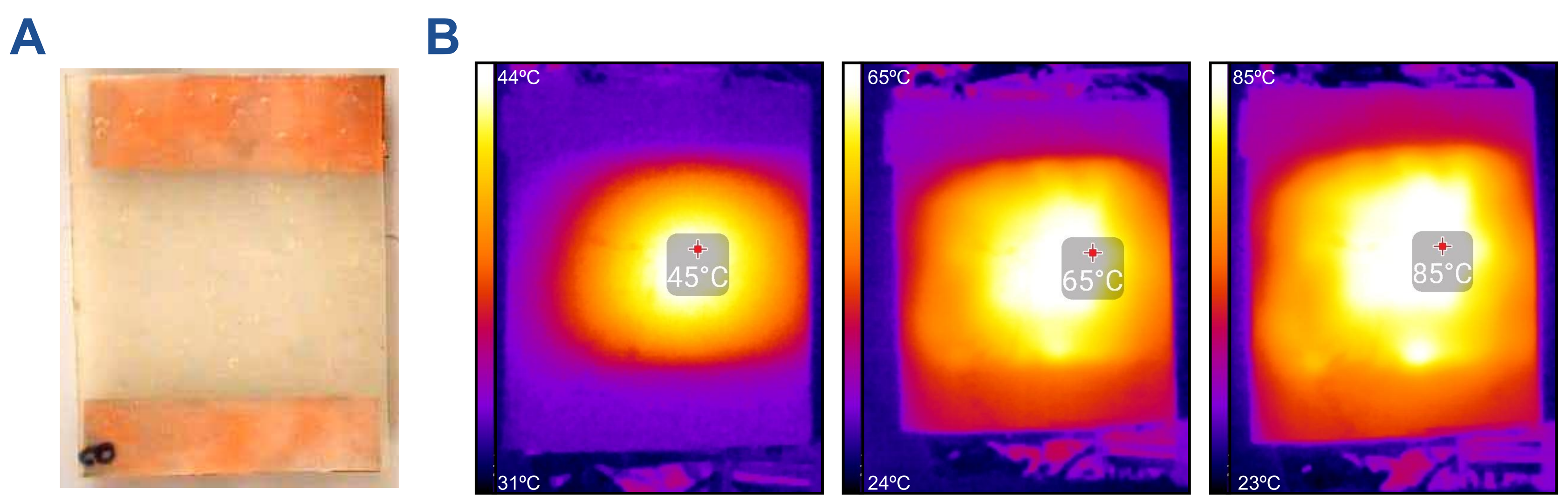


Figure 4. *Images of AgNW-PLA heater.* ***(A)*** *Standard camera image demonstrates transparency of AgNW-PLA.* ***(B)*** *Infrared thermal images of AgNW-PLA heater across different temperatures (left to right: 45ºC, 65ºC, 85ºC).*

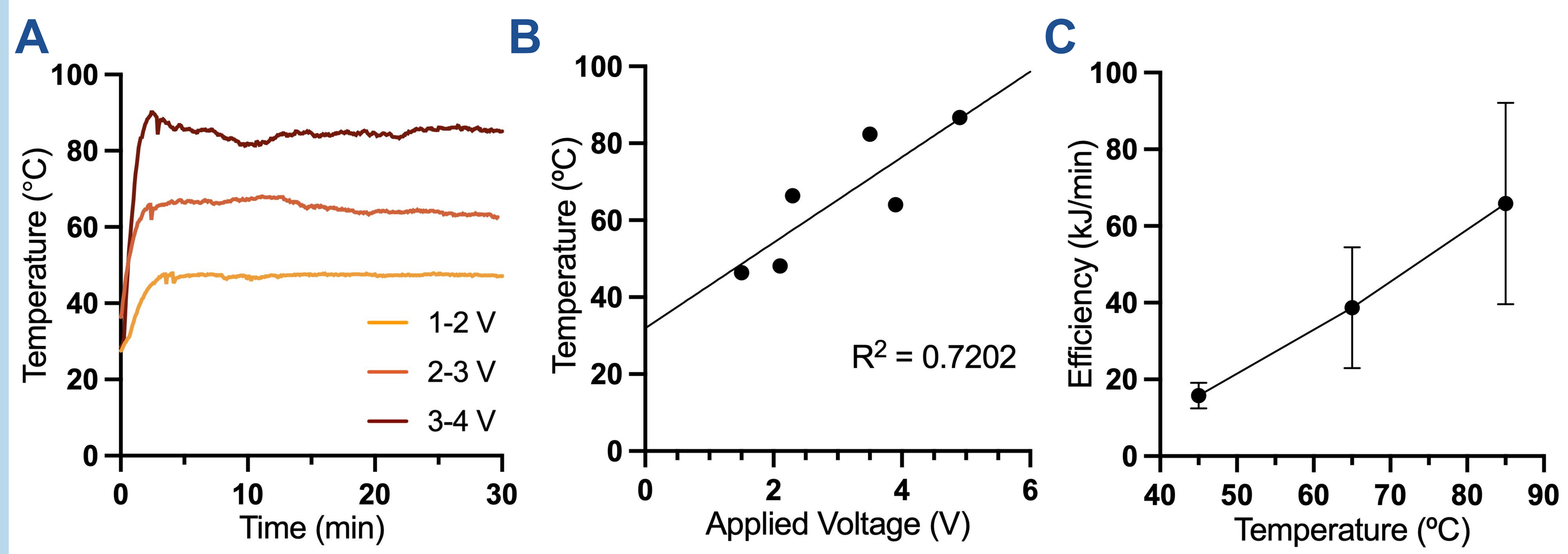


Figure 5. ***(A)*** *Heating stability of AgNW-PLA heater. Plot shows average temperature across replicates. Each replicate (n=2) required slightly different voltage to reach target temperatures (45ºC, 65ºC, 85ºC); voltage range shown in legend.* ***(B)*** *Relationship between applied voltage across copper electrodes and temperature of AgNW-PLA heater demonstrates linear pattern.* ***(C)*** *Efficiency (kJ/min) of AgNW-PLA heaters at different temperatures (n=4).*

Demonstration of heating ability for molecular diagnostics: RT-LAMP for SARS-CoV-2 detection

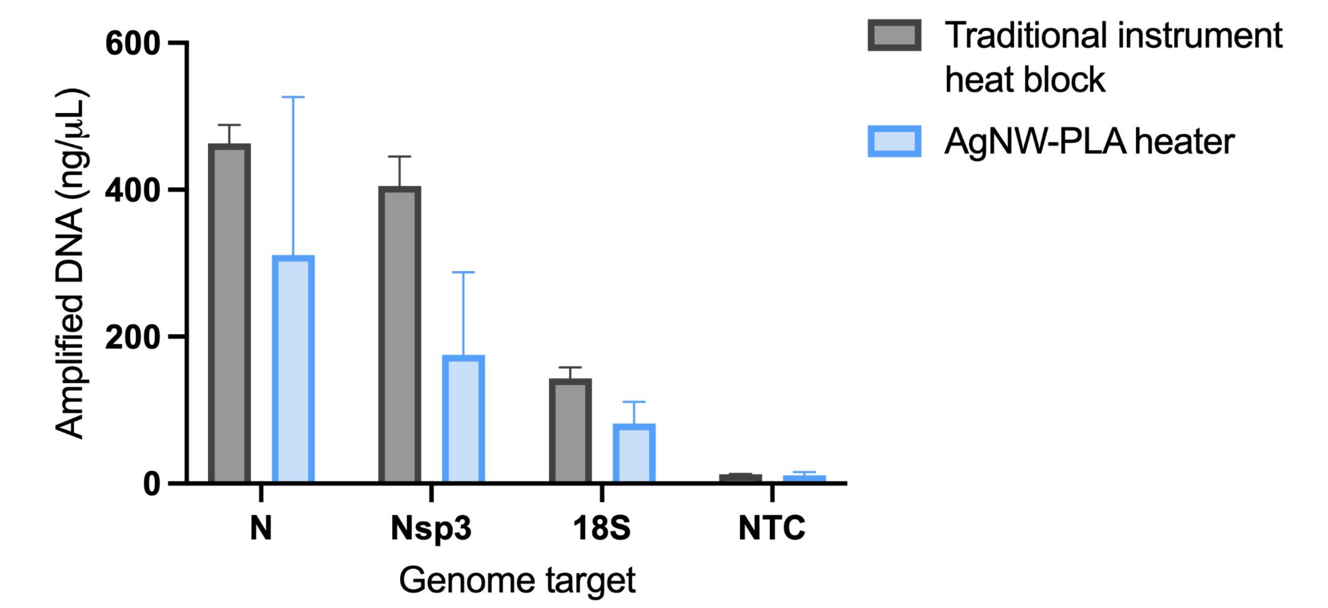


Figure 8. *Endpoint quantification of amplified DNA from RT-LAMP assay to detect SARS-CoV-2 shows* ***successful amplification*** *of 2 SARS-CoV-2 genome targets (N, Nsp3) and positive control (human 18S rRNA), and none for negative control (NTC). Starting concentration was 10^5 copies/mL inactive virus spiked in human saliva (n=3).*

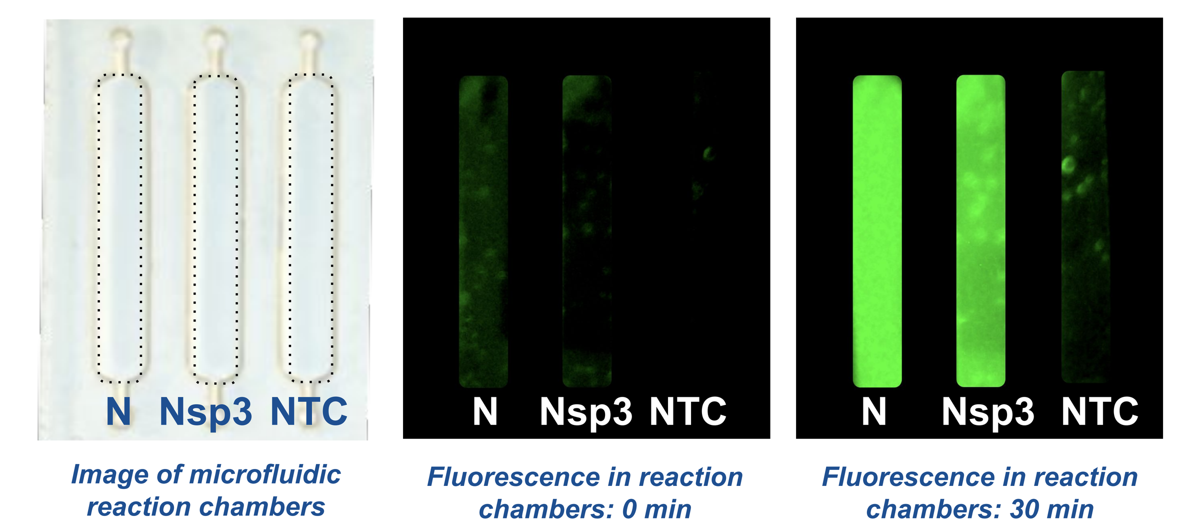


Figure 9. *Fluorescence RT-LAMP visualizes amplification difference between SARS-CoV-2 targets (N, Nsp3) and negative control (NTC).*

Conclusion

- AgNW-PLA heater demonstrates **fast response** and **stable heating**
- AgN-PLA heater exhibits **high conductivity** and **great Joule heating efficiency**.
- AgNW-PLA heater allows for s**uccessful detection of SARS-CoV-2** on a microfluidic chip via **RT-LAMP molecular diagnostic assay.**
- The **biodegradability** of PLA simplifies disposal processes and promotes sustainability.
- Combining the compact design with the high sensitivity and accuracy molecular diagnostics can offer, these diagnostic tools signify great potential for application in point-of-care and resource-constrained environments.

Future Work

- Optimize heating distribution by implementing different coating methods
- Enhance contact between copper plates and silver nanowire to improve conductivity and uniform distribution
- Explore alternative conducting nanomaterials such as iron, zinc, or magnesium for improved biosafety during biodegradability

Acknowledgement

Thanks to SURE program and Dr. Sia for this amazing opportunity. Special thanks to Abby for her tremendous support and reliable mentorship.

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The Fu Foundation School of Engineering and Applied Science