Designing a Transistor-Based Blood Typing Sensor

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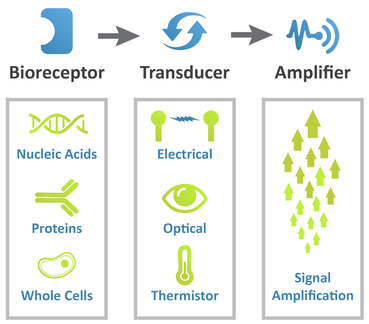
Introduction and Background

Electronic Biosensors



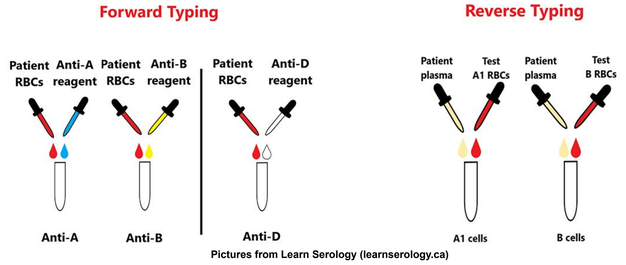
Picture from InnovoGene Biosciences (innovogene.com)

Blood typing is a pivotal test and is required for numerous medical techniques. The standard method for blood typing is forward and reverse typing, which can be slow and involves an extensive process. Therefore, a low-cost electronic biosensor for the determination of an individual's blood type could improve time to care and decrease errors due to unknown blood type.

Electronic biosensors convert a biological response into an electrical signal and are known for rapid results and high specificity of measurements. Due to these benefits, electronic biosensors have been incorporated into a variety of different fields, such as diagnostics and clinical medicine.

Blood Typing

In the past, blood typing has typically been performed using forward and reverse typing.



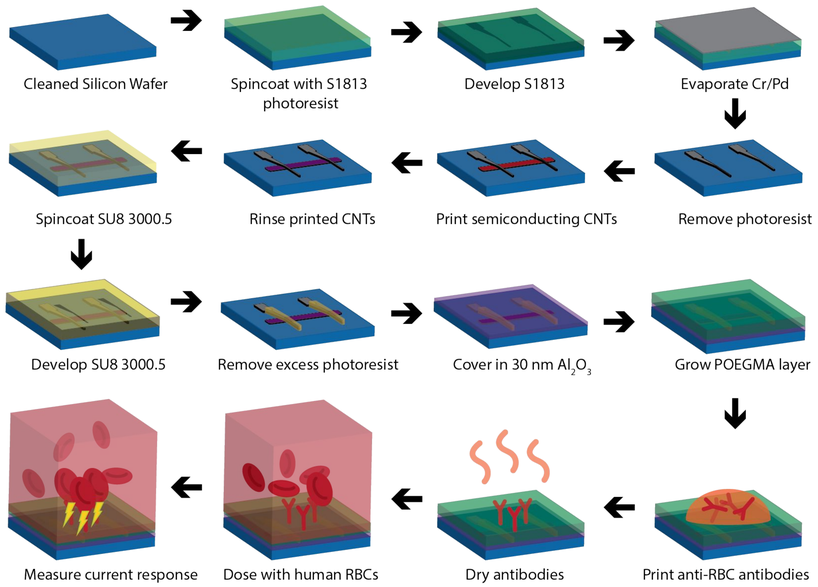
Pictures from Learn Serology (learnserology.ca)

- Forward typing determines the presence or absence of A and B antigens on a person's red blood cells with anti-A and anti-B sera.
- Reverse typing finds ABO antibodies in a person's serum.

Drawbacks to Traditional Blood Typing Test

- Both processes must be performed consecutively, leaving little room for errors.
- Additionally, it can take several minutes to read results.
- This method also requires a large amount of blood to obtain a person's blood type.

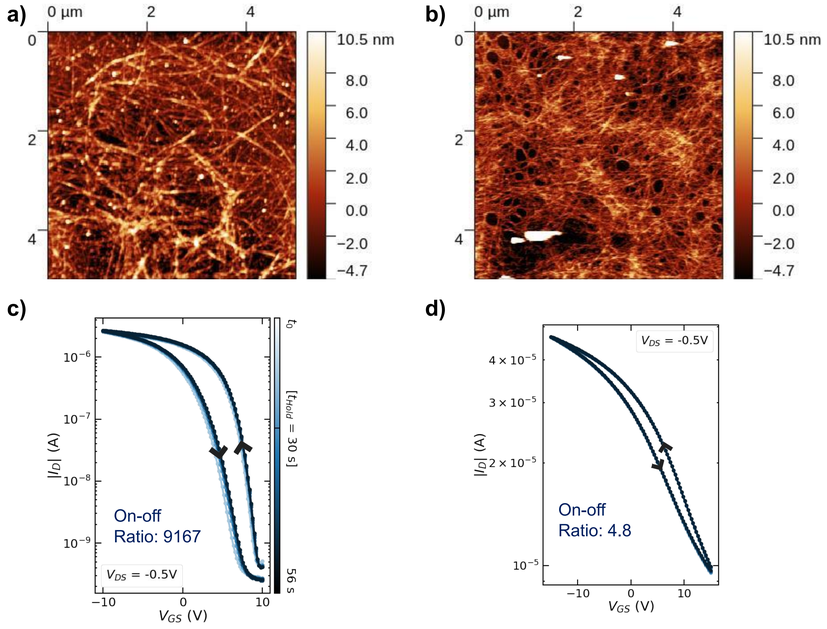
Fabrication of Chips



Results

Transistor Improvements

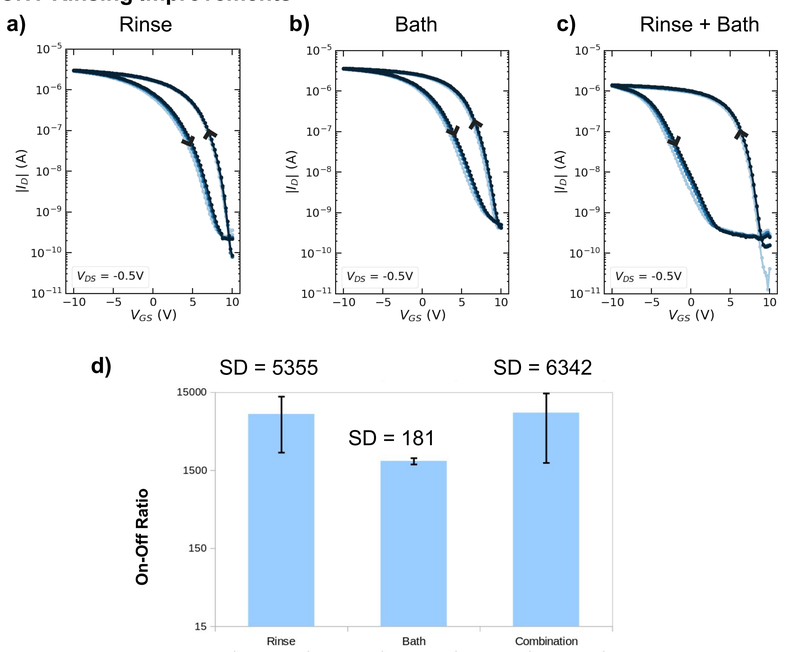
Carbon Nanotube (CNT) Printing Improvements



CNT Printing. CNT channel printed with (a) 1 pass and (b) 2 passes. Transfer curve of transistor with (c) 1 pass and (d) 2 pass of CNTs printed.

2 passes produces a dense network of CNTs, resulting in a lower on-off ratio

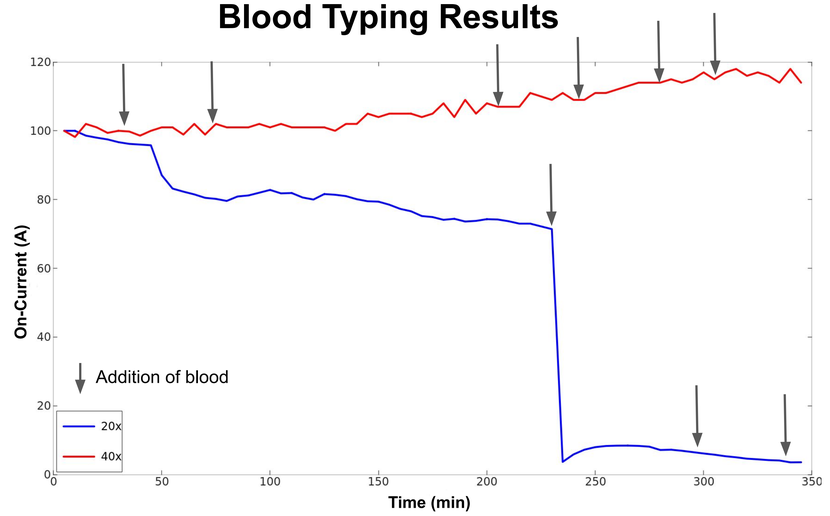
CNT Rinsing Improvements



CNT Rinsing Techniques. After printing, CNTs were rinsed by (a) rinsing with toluene for 15 seconds, (b) hot toluene bath for 3 minutes, or (c) rinsing the CNTs with both a 15 second toluene rinse followed by the 3 minute hot toluene bath. (d) Average on-off ratio recorded and variability of devices.

The 3 minute hot toluene bath produces the most repeatable devices, shown by the low standard deviation between devices.

Blood Typing Results



The above graph shows the on-current measurements of a blank (unfunctionalized) chip spiked with aliquots of 20x and 40x dilution of blood. There should be minimal change in the measured on-current when 10 ul of blood is added; however, adding 20x diluted blood produces a change in on-current. Since there are no printed antibodies on the blank chip, this is likely due to oversaturating the device with RBCs.
This comparison helped to determine which dilution of blood should be used when testing devices with anti-RBC antibodies, as the only current modulation should occur due to binding of red blood cells to the anti-RBC antibodies.

Conclusions and Future Work

Printing one pass of CNTs produced a higher on-off ratio, which resulted in better device functionality. It was also observed that rinsing the CNTs with a 3 minute hot toluene bath resulted in consistent transfer curves where an on-off ratio of four orders of magnitude occurred. Rinsing the CNTs with just a 15 second rinse produced inconsistent devices, with some devices producing a lot of leakage current. Rinsing with a combination of the 15 second rinse and toluene bath also produced inconsistent devices, where many were shorted. From these results, it can be concluded that the initial seconds of the rinse process determine how well the chip functions, and since the toluene bath provided a more uniform rinse, it should be used as the primary rinse method.

A 40x dilution of blood is ideal for testing as a blank device saw current modulation with a 20x dilution. This is most likely because the 20x dilution had too many red blood cells, which flooded the device.

Future Work

- Optimize the soak time for post printing in hot toluene bath.
- Print antibodies on chips that were rinsed with hot toluene.
- Obtain repeatability data with functionalized devices.

References

[1] Joh, D.Y. et al. Inkjet-printed point-of-cae immunoassay on a nanoscale polymer brush enables subpicomolar detection of analytes in blood. Proceedings of the National Academy of Sciences. (2017).
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