In-vitro Model and Analysis of Gold Nanoparticles for Glucose Sensing in Skin

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Introduction

Diabetes mellitus is a chronic condition that can lead to severe complications if untreated. It is primarily manifested as Type 1 (T1D) and Type 2 (T2D) diabetes, with T1D often requiring insulin therapy due to an absence of insulin production, and T2D typically associated with lifestyle factors leading to reduced insulin sensitivity. Traditional glucose monitoring relies on self-monitoring of blood glucose via finger-prick. Analysis is done using meters and test strips, which are effective but costly and blood sampling can be painful. To address these issues, this thesis focused on developing microneedle (MN) patches using biocompatible polymers for minimally invasive glucose monitoring.

Materials and Methods

The fabrication of MN patches included designing master molds using CAD software, creating Polydimethylsiloxane molds, and exploring various polymers. Besides self-made 3D printed molds, laser-fabricated molds from Blueacre (BA) Technology Ireland were purchased and used for MN patch fabrication (Figure 1). Polyvinyl alcohol (PVA) and Polyvinylpyrrolidone (PVP) solutions were prepared, and patches were fabricated through a micromolding technique. Linolenic acid containing gold nanoparticles (GNP@LN) for glucose sensing was incorporated into the polymer solutions and they were analyzed using a UV/Vis spectrometer (Jasco V-730 Spectrophotometer, UK) and a spectrofluorometer (Jasco FP-8300 Spectrofluorometer, UK).

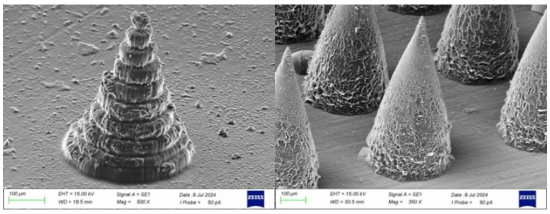

Fig. 1 Scanning Electron Microscope images of MN patches. Left: MNs fabricated from the self-made mold, which show step-like features because of the 3D printing process. Right: MNs from the purchased BA mold.

The UV/Vis spectrometer was employed to find the Localized surface plasmon resonance (LSPR) of the GNP@LN to investigate if the synthesis of the GNPs worked. A spectrofluorometer was used to investigate the emission spectra of the solutions at an excitation wavelength of 400 nm (Figure 2).

Results

PVP proved too brittle for MN patch fabrication, while PVA demonstrated good mechanical strength. The tighter interspacing of the BA patches, resulting in a smaller array size, produced more robust MN patches as shown during dissolution experiments in agarose gel. Aqueous emulsions containing GNP@LN were successfully emulsified and showed oil droplets of a maximum size of 20 μm. These emulsions showed an absorbance or fluorescence signal only in the absence of PVA.

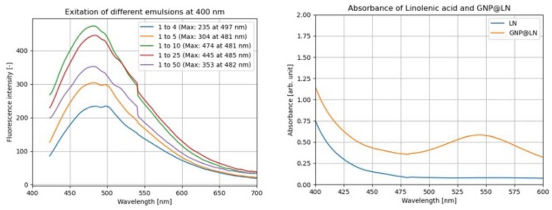

Fig. 2 Left: Emission spectra of emulsions containing different amounts of GNP@LN without PVA. Right: The absorbance of LN together with the absorbance of GNP@LN are shown. The addition of GNPs reveals an LSPR at a wavelength of approximately 540 nm.

Discussion

This thesis identified sharp needle tips and array size as crucial factors affecting mechanical stability. Lower PVA concentrations dissolved faster, suggesting that higher concentrations are preferable for more robust patches, particularly when incorporating GNP@LN. The addition of PVA into the emulsions inhibited any fluorescence or absorbance signals, suggesting that PVA may cause quenching effects or disintegration of the GNPs in LN.

References

M. Nasehi, M. Saeedi, J. Ghanavi, and M. Moravvej-Farshi, "Glucose sensing based on the interaction of gold nanoparticles@linoleic acid with the glucose," IEEE Sensors Journal, vol. 22, no. 7, pp. 7169–7176, 2022.

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