Label-Free Detection of Glucose and Lactate Using Terahertz Chemical Microscope with Aptamer-Functionalized Sensing Plates

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1. Introduction

Glucose and lactate are key biomarkers for conditions such as diabetes and lactic acidosis, necessitating rapid and highly sensitive detection methods. Conventional approaches often rely on labels or enzymes, which involve complex procedures and limited sensitivity.

In this study, we employed a Terahertz Chemical Microscope (TCM) combined with aptamer-functionalized sensing plates to enable label-free and real-time detection of glucose and lactate. By utilizing dielectric changes at the sensing surface, this method offers a promising approach for advanced biosensing applications in the medical field.

2. Method

To detect glucose and lactate with high sensitivity, we employed a Terahertz Chemical Microscope (TCM) equipped with aptamer-functionalized Silicon-on-Sapphire (SOS) sensing plates. Each aptamer was immobilized onto the surface of the SiO_2 layer using a BS3-based crosslinking protocol following surface modification with NaOH and APTES [1].

After aptamer immobilization, target molecules (glucose or lactate) at various concentrations were introduced to the wells containing the sensing plates. Terahertz amplitude was measured before and after molecular binding. The spatial mapping of the THz amplitude was performed using an X-Y stage controlled via LabVIEW, and detection was carried out using photoconductive antenna sensors under femtosecond laser excitation.

3. Resalt

The terahertz amplitude changed significantly in response to the binding of glucose or lactate to their respective aptamers. This change correlated with concentration in both cases. As shown in Figures 1 and 2, the terahertz amplitude varied systematically with glucose and lactate concentrations, respectively.

For glucose, a monotonic increase in amplitude was observed with increasing concentration, demonstrating the feasibility of quantitative detection. For lactate, distinct amplitude shifts were confirmed across a wide dynamic range, from 0.1 mM to 100 mM.

The results confirmed that TCM enables highly sensitive, real-time, and label-free detection of small biomolecules. Reproducibility was verified through repeated measurements, and amplitude stability was maintained over the course of experiments.

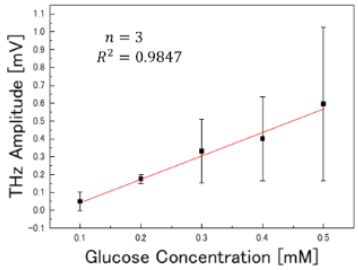

Fig.1 Correlation Between Glucose Concentration and Terahertz Amplitude

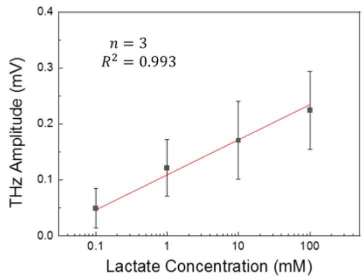

Fig.2 Correlation Between Lactate Concentration and Terahertz Amplitude

4. Conclusion

In this study, we investigated a detection method combining aptamer-functionalized sensors with terahertz chemical microscopy for identifying medically important small molecules such as glucose and lactate. The proposed approach is non-invasive and label-free, demonstrating its potential applicability to diabetes management and lactic acidosis monitoring.

References

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