High-Risk Factor Detection of Coronary Artery Disease by Terahertz Spectroscopy

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***Abstract*—Methylglyoxal (MGO) is an important high-risk factor of coronary artery disease. While the existing detection methods for MGO are time-consuming and high-cost. Here we demonstrate that the terahertz spectroscopy can be used to qualitatively identify the abnormally high concentration of MGO and quantitatively analysis the normal MGO blood concentration.**

I. INTRODUCTION

Coronary artery disease (CAD) is a common type of heart disease. In the past decade, it has become the main cause of death worldwide due to its high morbidity and mortality rate. Recently, researchers found that methylglyoxal (MGO) concentration in blood is critical for the onset and progression of CAD. Therefore, the precise detection of the MGO concentration is meaningful to the early diagnosis and clinical treatment of CAD. Currently, the major method for MGO detection is high-performance liquid chromatography (HPLC) and liquid chromatography-mass spectroscopy (LC-MS). But these methods require expensive instruments and long-time samples pre-preparation processing, and thus cannot be widely used in clinical application yet. Terahertz (THz) spectroscopy has been considered as a promising biomedical detection method, due to its advantages of low-cost, non-destructive and high sensitivity. [1-3] Therefore, we propose a simple, fast and accurate method for MGO detection by using THz spectroscopy.

II. RESULTS

Due to the THz peaks of MGO are not sharp or strong enough to be precisely identified at trace concentration, we use o-phenylenediamine (OPD) to chemically react with MGO to form an adduct product 2-methylquinoxaline (2-MQ), which has multiple strong THz peaks. The corresponding reaction equation shows in Fig. 1(a). The THz spectra of MGO, OPD, and their product are presented in Fig. 1(b)-(d). These three chemicals have different THz peaks. By contrast, the strongest peak of 2-MQ (407 cm^{-1}) is much higher than that of MGO (87 cm^{-1}). These results benefit spectral identification and analysis.

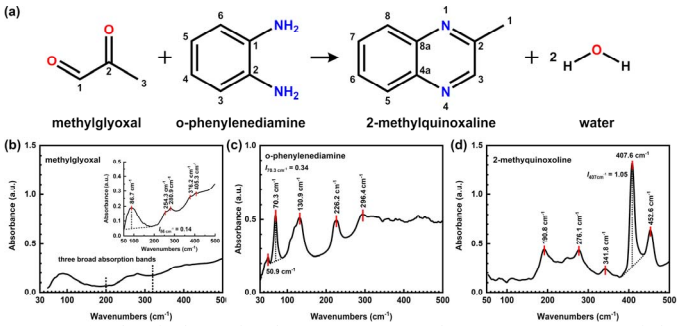

Fig. 1. (a) Chemical reaction between MGO and OPD. THz spectra of (b) MGO, (c) OPD and (d) their product, 2-MQ.

Then we demonstrate that the THz peaks of OPD can be used to judge whether the concentration of MGO is abnormally excessive. Fig. 2(a) shows the THz spectra of the chemical reactions with different molar ratios of MGO/OPD. When the mole number of MGO is more than that of OPD (MGO/OPD = 4:1, 2:1, 1:1), only THz peaks of 2-MQ can be observed. While the mole number of MGO is less than that of OPD, it can not only show these 2-MQ peaks but also show the THz peaks of OPD. Therefore, by setting the mole number of OPD as the upper limit of the MGO normal range, we can analyze whether the MGO concentration is abnormal excessive based on the THz peaks of OPD.

Furthermore, we demonstrate the strongest THz peak of 2-MQ provides a sensitive index for the quantitative detection of MGO. The THz spectral changes induced by an increase of MGO concentration, are presented in Fig. 2(b) and (c). There is a linear relationship between the peak intensity at 407 cm^{-1} (y, arb. unit) and the MGO concentration (x, nmol/mL). The corresponding function formula is $y = 2.96\times10^{-5}\times x$, with a correlation coefficient of 0.999. Finally, we use this method to test blood samples, whose MGO concentrations are 100 nmol/mL, 150 nmol/mL, and 200 nmol/mL respectively. as shown in the inset of Fig. 2(c), the results of blood samples (red triangles) keep in line with the fitted line, indicating high reliability of this detection method.

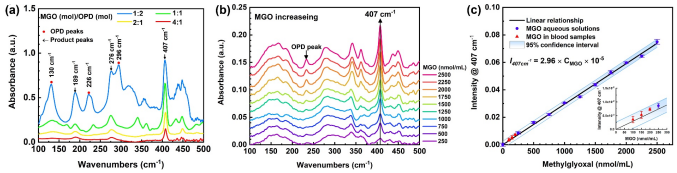

Fig. 2. THz spectra changes induced by (a) different molar ratio of MGO/OPD, and (b) an increase of MGO concentration. (c) Intensity of 407 cm^{-1} peak, as a function of MGO concentration.

III. SUMMARY

Here we demonstrate a new analysis method for MGO, which is critical for CAD patients. With this method, we can not only qualitatively identify abnormally accumulation of MGO, but also quantitatively detect MGO concentration from 5 to 2500 nmol/mL.

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