

# 利用奈米表面改質提升QCM偵測蘭花嵌紋病毒的靈敏度:以單壁奈米碳管與奈米金作表面修飾

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## 中文摘要

本論利用單壁奈米碳管 (single-wall carbon nanotube) 與 37 nm 奈米金 (gold nanoparticles) 修飾石英晶體微量天平 QCM (quartz crystal microbalance) 使其在蘭花嵌紋病毒的及時檢測具有高靈敏度。首先利用單壁奈米碳管在電極的修飾，接著利用化合物 CDI-Tween 20 (1,1'-carbonyldiimidazole-activated Tween 20) 來交聯單壁奈米碳管與抗體，完成偵測前的修飾。藉由單壁奈米碳管的修飾，當檢測病毒濃度在  $0.1 \mu\text{g mL}^{-1}$  時的靈敏度可由  $2.18 \text{ Hz ng}^{-1}$  提升至  $11.5 \text{ Hz ng}^{-1}$ ，檢測極限也由  $2.08 \text{ ng}$  提升至  $0.502 \text{ ng}$ 。此外，經修飾後的檢測平台成功的應用於蘭花嵌紋病毒的定量。比較起酵素免疫法 ELISA (Enzyme-linked immunosorbent assay)，單壁奈米碳管修飾 QCM 的檢測方式可達到相同的靈敏度且具有快速、便宜的優點，此研究提供了一個能快速檢測與定量蘭花嵌紋病毒的平台。

接著利用 37 nm 奈米金修飾 QCM 使其提升其靈敏度及鍵結效應。我們發現利用 0.5 v/v % 的烷基雙硫醇修飾金電極表面可達到最高的奈米金覆蓋率 (35.5%)，經修飾後的

QCM在偵測0.5 ng 蘭花嵌紋病毒的靈敏度可由4.62 Hz ng<sup>-1</sup>提升至 48.1 Hz ng<sup>-1</sup>，檢測極限也由1 ng提升至0.1 ng。本論文發現表面電荷的增加可提升石英震盪的基頻且增加其靈敏度，而表面能的增加可提升感測器的生物鍵結效應。



# **Nanoscale surface modification promotes ultra-sensitive detection of quartz crystal microbalance against cymbidium mosaic potexvirus: single-wall carbon nanotube and gold nanoparticles**

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## **Abstract**

We have developed an ultra-sensitive, convenient, real-time platform for detecting Cymbidium mosaic potexvirus (CymMV) based on single-wall carbon nanotube (SWNT)-functionalized quartz crystal microbalance (QCM) sensors. Functionalization was achieved by coating the QCM electrode with SWNTs, followed by 1,1'-carbonyldiimidazole-activated Tween 20 (CDI-Tween 20) modification and conjugation of antibodies. Sensitivity was enhanced from 2.18 Hz ng<sup>-1</sup> to 11.5 Hz ng<sup>-1</sup> when 0.1 μg mL<sup>-1</sup> CymMV was applied. The low limit of detection of SWNT-functionalized QCM sensors was improved from 2.08 ng to 0.502 ng. The SWNT-functionalized QCM sensor was successfully used to quantify the amount of CymMV contained in infected orchid leaves. Compared to ELISA, SWNT-functionalized QCM sensors are fast, economical, and ultra-sensitive, with comparable sensitivities. The current study demonstrates the application of QCM sensors as a convenient platform to detect and quantify CymMV.

We modified the surface of QCM electrode with 37-nm GNP and found that the

sensitivity and capacity of detection was significantly enhanced. Maximum surface coverage of 35% occurred when 0.5% 1,6-hexanedithiol was applied as cross linking agent. A 10-fold enhancement of sensitivity was observed at 0.52 ng CymMV, from 4.62 Hz ng<sup>-1</sup> to 48.1 Hz ng<sup>-1</sup>. Limit of detection is improved from 1 ng to 0.1 ng. Modification of GNP enhanced 10 folds in sensitivity and in LOD.

Increase in surface charge was observed which in theory enhanced fundamental resonating frequency ( $F_0$ ). Ultra-sensitive detection of modified QCM was correlated to the increase in surface charge. Increase in surface energy was also observed which was correlated to the increased in binding capacity of QCM electrode.



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