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Graphene-based Electrochemical Biosensor for High-Performance Bacterial Detection in Aqueous Environments

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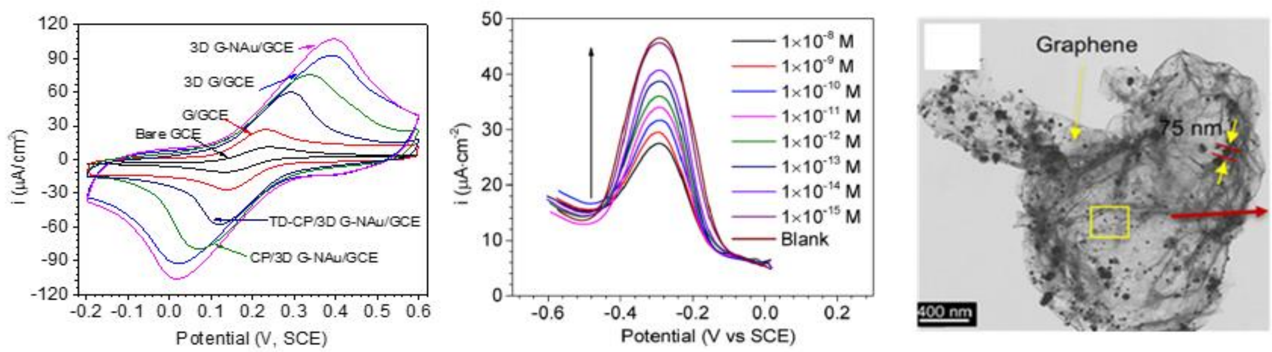
Graphical Abstract



Abstract

Statistics shows that microbiologically induced corrosion (MIC) is responsible for over 75% of corrosion in oil wells, and for nearly50% of failures of pipeline systems. Of various microorganisms causing metallic corrosion, sulphate-reducing bacteria (SRB) are the most principal culprits because they are responsible for a half of all the instances of MIC. Nowadays, three types of protocols have been used for SRB detection in service environments, i.e., traditional culturing methods, immunological techniques and molecular biological techniques, evaluating the occurrence MIC at its early stage. Although the methods such as most probable number (MPN), enzyme-linked immunosorbent assay and polymerase chain reaction (PCR) can provide results for SRB diagnosis, they are usually quite time-consuming, and require sophisticated instrumentation that may result in either a poor bio-selectivity or a low sensitivity.

Electrochemical biosensors utilize biological materials to recognize target molecules while producing electrochemical signals. They have unique advantages in detecting bacteria such as SRB with a rapid response, high sensitivity, proper selectivity, and low cost. Furthermore, graphene shows a promising property in biological detection. To date, most of electrochemical sensors made of graphene or graphene-based composites for bioanalysis have been based on the two-dimensional structure of the graphene. To fully use the high specific surface area of graphene in practice, a 3-

dimensional (3-D) structure is preferred. It is expected that it will enable a sensitive and reliable performance for SRB detection.

In this work, an electrochemical biosensor based on 3-D graphene/gold nanoparticles was developed for SRB detection. The technique combined the high selectivity of nucleic acid hybridization by genetic marker with a high sensitivity of electrochemical analytical method for the purpose. Processing parameters were optimized to maximize the detection capability, and various testing and analysis techniques were used to characterize the performance of the biosensor. The biosensor shows a high sensitivity, with the detection limit up to 9.41×10^{-15} M of the target DNA. Moreover, the biosensor successfully detects the DsrAB DNA in the fluid collected from an oilfield and shows an improved detection limit than both gel electrophoresis and the quantitative reverse transcription polymerase chain reaction methods.

Keywords: Electrochemical biosensor; graphene doped gold nanoparticles; sulphate-reducing bacteria; electrochemical response.

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Biography of Presenting Author

Frank Cheng is a Professor and Canada Research Chair at the University of Calgary. He is an internationally recognized researcher in Corrosion Science, Advanced Materials, Micro- and Nano-Electrochemical Measurements, and Pipeline Engineering. Dr. Cheng has authored 3 books and 250+ journal papers. The total citations of his publications exceed 12,000, with a H-index of 68 (Google Scholar). He is the recipient of numerous prestigious awards, including the International Association of Advanced Materials (IAAM) Medal, Uhlig Award and Technical Achievement Award of National Association of Corrosion Engineering (NACE) International, Metal Chemistry Award of Canadian Metallurgy and Materials Society, etc. Dr. Cheng was named as Canadian Distinguished Materials Scientist in 2019. He is elected Fellows of NACE International, the Institute of Corrosion (ICorr, UK) and Chinese Society for Corrosion and Protection (CSCP). He was elected into the European Union Academy of Sciences (EUAS) in 2018. Dr. Cheng is now serving as the Editor-in-Chief of Journal of Pipeline Science and Engineering (Elsevier/KeAi). He obtained a Ph.D. degree in Materials Engineering at the University of Alberta in 2000.

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