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Electrochemical Amyloid β Immunosensor Based on $Ti_3C_2T_x$ MXene Nanosheets

Antonio S. Garcia[1], Angelina K. Locke[1], Bryson D. Core[1], Bhoj R. Gautam[1], Daniel E. Autrey[1], and Shubo Han[1,*]

[1]*Department of Chemistry, Physics, and Materials Science, Fayetteville State University, NC, USA*
*Corresponding author: shan@uncfsu.edu

Alzheimer's disease (AD) is the most common neurodegenerative disease and a major health-care problem. More than 55 million people in the world, including 6.7 million Americans, are living with AD. As AD is characterized by production and deposition of β-amyloid peptide (Aβ) in the brain, Aβ is considered as a potential biomarker for diagnosing and monitoring the progression of AD. Nanomaterials-based electrochemical immunosensor is one of the most promising methods for early diagnosis and therapeutic of AD, due to its highly selective, sensitive, and label-free advantages. The graphene-like two-dimensional (2D) MXene nanosheets have shown large surface area, good conductivity, biocompatibility, high ion transport, and low diffusion barrier, attracting attention in recent years to use it as the nanomaterial substrate for biosensor fabrication [1, 2]. In this work, we presented a $Ti_3C_2T_x$ MXene nanosheets-based electrochemical immunosensor to detect trace Aβ for early diagnosis of AD.

$Ti_3C_2T_x$ MXene nanosheets were first prepared by chemically etching the milled Ti_3AlC_2 powder in a stirring solution of lithium fluoride and hydrochloric acid (LiF/HCl) for 24 hours in room temperature to remove Al, centrifuged at 4500 rpm for 10 min and further washed with 6 M HCl and deionized water, respectively. The resultant samples were centrifuged to collect green-color supernatant. This 2D MXene nanosheets were vacuum filtered and air dried before use [3]. Scanning electron microscopy (SEM) image of MXene was collected before immobilization to confirm the nanosheet formation.

The $Ti_3C_2T_x$ 2D MXene nanosheets were fixed onto indium tin oxide (ITO) electrode surface by conductive carbon glue. The immobilized MXene nanosheets were then chemically modified with amino groups by using aminosilane (APTES), and next were immersed in a crosslinking solution 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDC) and N-hydroxysuccinimide (NHS) to obtain active surface with well-distributed carboxyl functional groups for anti-Aβ binding. After that, anti-Aβ was immobilized to the nanostructure surface, followed by blocking the free carboxyl ends by binding bovine serum albumin (BSA) [4, 5]. Tapping mode atomic force microscopy (AFM) images (Resolution of 512 px× 512 px and a scanning rate of 1 line/s with a normal frequency 65 kHz and a normal spring constant of 0.35 N/m) were collected for the immunosensor surface.

Finally, electrochemical immunosensors were tested for Aβ solutions by using electrochemical impedance spectroscopy (EIS) and cyclic voltammetry in the presence of 0.1 mM potassium ferricyanide, $K_3Fe(CN)_6$. The detection limit of the prepared MXene-based Aβ immunosensor can reach 0.01 pg/mL, a level that can be used for AD early diagnosis (Fig. A). Fig. B shows the SEM image of prepared $Ti_3C_2T_x$ MXene, which presents a layered structure that can be used for sensor development. Fig. C shows the topographic AFM image of MXene immobilized at the ITO surface. Nanosheets structures were observed with the length between 0.3-1.5 μm, the thickness between 3-10 nm, and the surface roughness (RMS) of 1.996 nm. Fig. D shows the topographic AFM image of the MXene-based immunosensor after interacting with Aβ. Compared to MXene-ITO surface (Fig. C), the nanosheets structure became fuzzy, surface roughness (RMS) increased to 3.682 nm. In the meantime, more nanoparticles were observed with the size of 3-10 nm, supporting the presence of antibody-Aβ complexes [6].

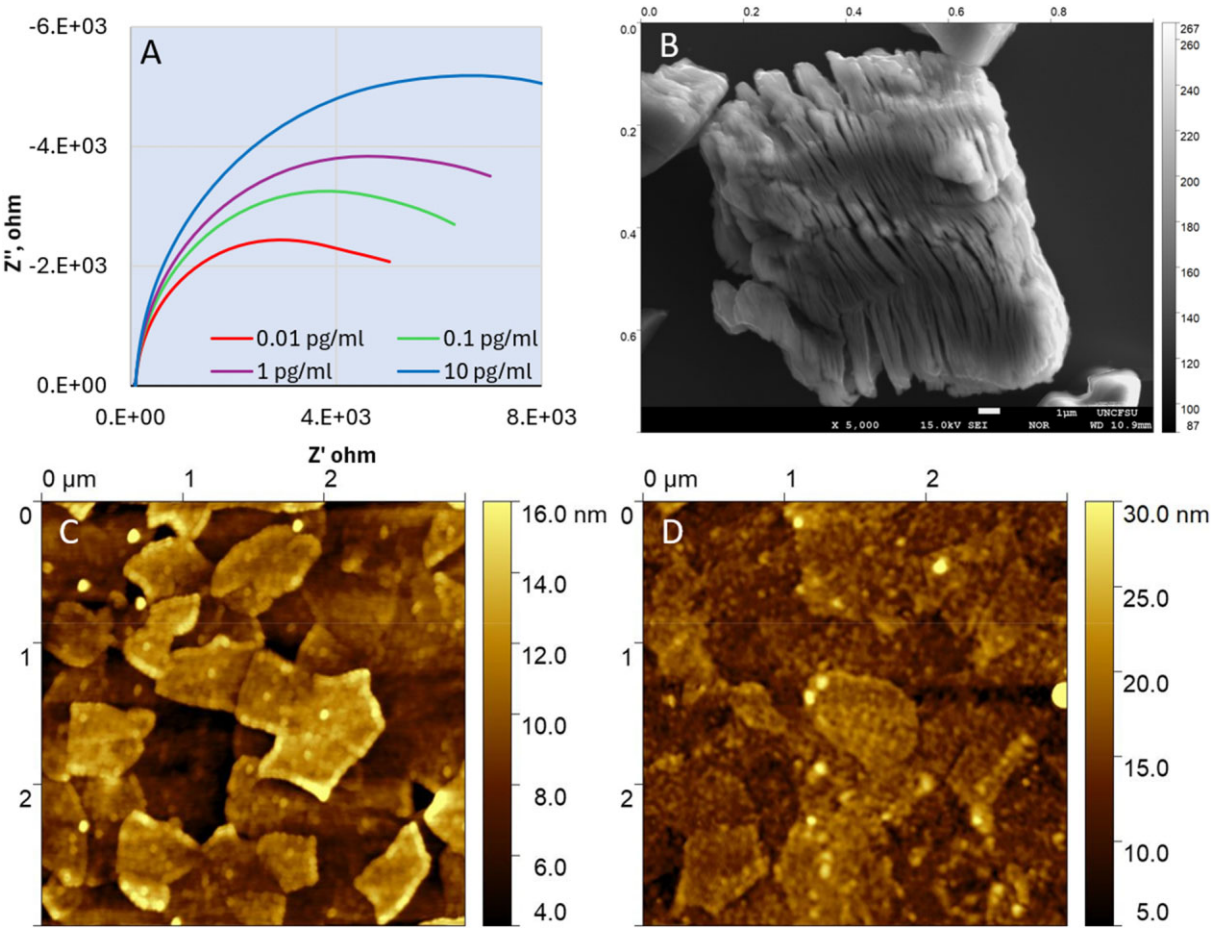

Figure 1. A. EIS spectra showed the Aβ immunosensor logarithmic response to the analyte between 0.01 to 10 pg/ml. B. SEM image of $Ti_3C_2T_x$ MXene showed layered structure. C. AFM image of 2D $Ti_3C_2T_x$ MXene immobilized on ITO surface. D. AFM image of 2D $Ti_3C_2T_x$ MXene-based immunosensor after reacting with Aβ at the surface.

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