DESIGN OF NOVEL GEL-FREE ELECTRODES FOR ECG AND EEG DATA ACQUISITION SYSTEM

***Project Reference No.**: 48S_MSC_0259*

College : JSS Science And Technology University, Mysuru
Branch : Department Of Chemistry
Guide(S) : Prof. N Kumara Swamy
Prof. U B Mahadevswamy
Student(S): Ms. Raveena H M
Ms. Usha H N

Keywords:

Heterojunction, Electrocardiogram, Electroencephalogram, Gel-free electrodes

Introduction:

ECG is one of the simplest and most widely used techniques for the clinical diagnosis of cardiovascular disease continuous ECG monitoring plays a crucial role in the early detection and treatment of many common heart conditions. One of the key components in ECG monitoring systems is the electrode. Currently, the most widely used commercial electrode is the Ag/AgCl wet electrode. This type of electrode requires the use of conductive gel. The gel not only ensures stable contact between the electrode and the skin but also serves as an electrolyte, enhancing the electrodes sensitivity. However, there are two main issues associated with conductive gels. Overtime, the gel tends to dry out, which increases the contact impedance between the electrode and the skin. This degradation affects the quality of the ECG signal and limits the duration for which continuous monitoring can be effectively performed. Moreover, extended contact between the conductive gel and the skin can cause irritation, discomfort, and even allergic reactions in some users. As a result, traditional Ag/AgCl electrodes are not ideal for long-term ECG monitoring. Among the innovations, flexible dry electrodes have emerged as a promising solution. They can be used directly on the skin without the need for gel or prior skin preparation, making them more suitable and comfort for prolonged ECG monitoring.

Objectives:

1. Synthesis of Cu-MOF/GQD@$MgSnS_4$ nanomaterials and characterization of the synthesized Cu-MOF/GQD@$MgSnS_4$

2. Preparation of PVDF/Cu-MOF/GQD@$MgSnS_4$ nanocomposite and its casting on dry Ag/AgCl button electrode.
3. Construction of a ECG and EEG data acquisition system and analysis of evaluation of sensor characteristics performance of sensor

Methodology:

Synthesis of Cu-MOF

Cu-MOF was prepared by hydrothermal method by taking 0.36 g of terephthalic acid and copper (II) nitrate trihydrate in 20 mL of DMF.

Synthesis of $MgSnS_4$

$MgSnS_4$ was obtained by hydrothermal method by taking 0.647 g of magnesium, 0.998 g of tin chloride, and 3 g of thiourea in 40 mL distilled water.

Synthesis of GQD

Graphene quantum dots (GQD) were obtained by one-step hydrothermal reaction that is 50 mg of glucose ,50 mL of deionized water, ethanol and distilled water.

Synthesis of Cu-MOF/GQD@$MgSnS_4$

Take 200 mg of Cu-MOF in a separate beaker, add 30 mL of DMF, and sonicate the mixture for 30 minutes. After sonication, stir the solution for another 30 minutes. Then, gradually add the $MgSnS_4$@GQD solution to the Cu-MOF mixture while continuous stirring. Once thoroughly mixed, filter the resulting solution and wash the residue with ethanol followed by water.

Fabrication of ECG electrodes based on PVDF/ Cu-MOF/GQD@$MgSnS_4$

A composite containing 12 mg of Cu-MOF/GQD@$MgSnS_4$ and 0.4 g of PVDF is blended into 25 mL of DMF to form a homogeneous suspension. Once fully dispersed, the mixture is drop-cast onto gel-free electrodes. After drying, the electrodes are used for ECG signal acquisition using an AD8232 heart monitor sensor connected to an Arduino UNO microcontroller.

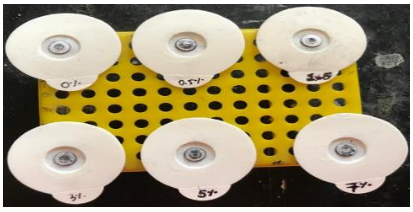

Figure 1: Representation of casted PVDF/ Cu-MOF/GQD@$MgSnS_4$ on gel-free electrode

Result and Conclusion:

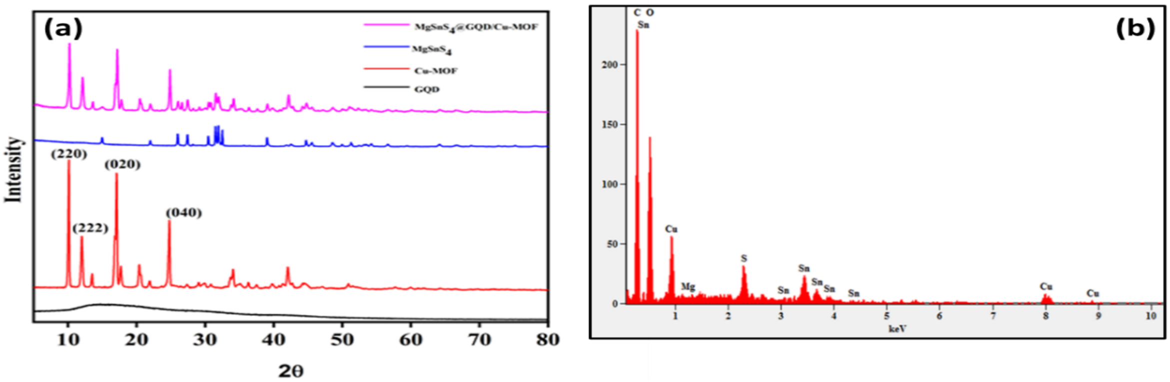

Figure 2: (a) XRD spectra, and (b) EDAX analysis of Cu-MOF/$MgSnS_4$

The XRD patterns of $MgSnS_4$, Cu-MOF, GQD, and the Cu-MOF/$MgSnS_4$@GQD nanocomposite were analyzed. Distinct diffraction peaks were observed for each material. Cu-MOF exhibited characteristic 2θ values at 9.94°, 13.71°, 17.03°, and 26.80°, while GQD showed a peak at 26.40°, corresponding to the (002) plane. $MgSnS_4$ displayed a few minor peaks. The composite material demonstrated good crystallinity, reflecting the successful integration of all components. Elemental composition of the materials was examined using energy dispersive X-ray spectroscopy (EDX). The spectra of Cu-MOF/$MgSnS_4$@GQD revealed distinct signals corresponding to carbon, oxygen, magnesium, sulfur, copper, and tin. XRD analysis confirms the successful crystalline formation of the Cu-MOF/GQD@$MgSnS_4$ nano-heterojunction, while EDX verifies its elemental composition.

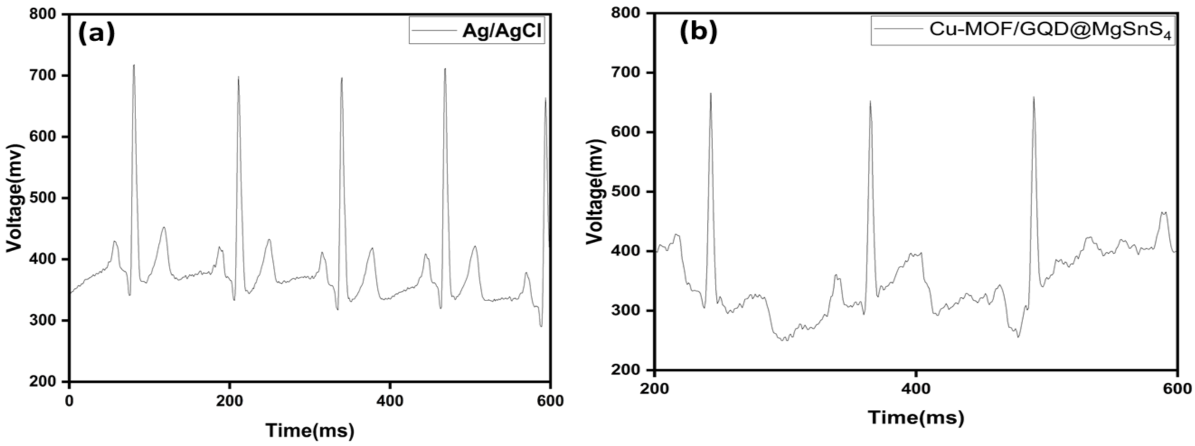

Figure 3: ECG signals of (a) Ag/AgCl, and (b) Cu-MOF/$MgSnS_4$

Compared to conventional Ag/AgCl electrodes, the PVDF/Cu-MOF/GQD@$MgSnS_4$-based electrodes exhibit enhanced signal characteristics, including improved R-R interval stability, higher R-peak amplitudes, and increased sensitivity. Based on the promising ECG data, future research will investigate the application of this material for EEG signal acquisition.

Future Scope:

The future scope of this project includes:

1. Further evaluation of the electrical behavior of the electrodes in relevant conditions.
2. Analysis of the reliability and clarity of ECG signals obtained for different concentrations and compositions using the dry electrodes.
3. Assessment of how safe and comfortable the electrodes are for prolonged skin contact.
4. Optimization of material properties to enhance conductivity and skin contact.
5. The PVDF/Cu-MOF/GQD@$MgSnS_4$ electrode material will be further explored for EEG signal monitoring.