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Direct electrochemical reduction of hydrogen peroxide catalyzed with copper (II) ions in the presence of polyacrylic acid and poly(2-acrylamido-2-methyl-1-propanesulfonic acid) as supporting electrolytes

INTRODUCTION

Hydrogen peroxide is an essential compound with significant chemical and biological importance. It is involved in oxidative reactions during biosynthesis and acts as a defense against bacteria, particularly in urine. However, elevated concentrations of hydrogen peroxide in breath can indicate serious diseases and disorders like asthma or lung cancer. Hence, there is a growing need for accurate and sensitive methods to determine its presence.

Polyacrylic acid (PAA) is a widely recognized polymer known for its exceptional absorption properties and high biocompatibility. Due to these characteristics, PAA has found extensive use as a polyelectrolyte in supporting electrochemical research. Its potential for the determination of hydrogen peroxide has been partly confirmed in scientific studies. It is hypothesized that **poly(2-acrylamido-2-methyl-1-propanesulfonic acid)** (AMPS) may exhibit similar or even improved properties, particularly in terms of its conductive nature.

The primary objective of this work is to present and evaluate the electrochemical performance of AMPS in the context of hydrogen peroxide determination in the presence of copper(II) ions, acting as a redox mediator. Additionally, a comparison is made between this method and the previously known method using polyacrylic acid as the supporting electrolyte.

METHODS

During the experiment, two sets of aqueous solutions of two polymers at various concentrations of hydrogen peroxide. The presence of copper(II) ions was maintained throughout all the tests.

To conduct the electrochemical measurements, a glassy carbon electrode served as the working electrode, a silver chloride electrode functioned as the reference electrode, and a platinum wire was used as the auxiliary electrode. Two different techniques, cyclic voltammetry, and square wave voltammetry, were employed for the electrochemical measurements of each solution. The calibration curves were established based on the current measured at a specific potential of -0.450 V.

ACKNOWLEDGEMENTS

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RESULTS

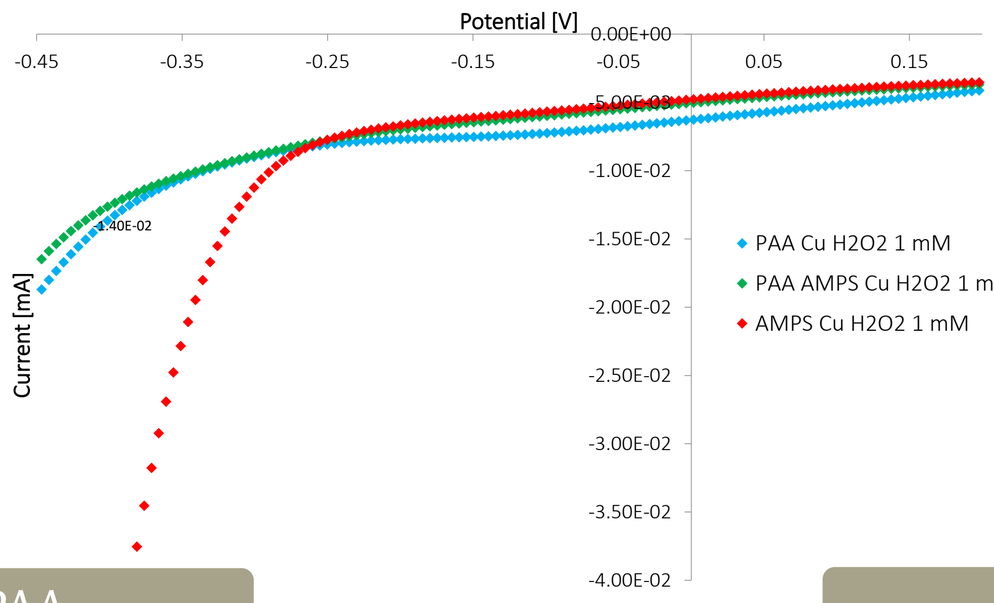

Fig 1. Comparison of square wave voltammograms for solutions:
PAA with Cu^{2+} ions and 1 mM H2O2 (blue),
AMPS with Cu^{2+} ions and 1 mM H2O2 (red) and a mixture of PAA,
AMPS with Cu^{2+} ions and 1 mM H2O2 (green).
Measurement conditions: step potential -0.005 V s^{-1}, amplitude 0.2 V, frequency 8 Hz.

EXPERIMENTAL

Substance:

H_2O_2(0.001 – 1 mmol)

Supporting electrolyte:

1% PAA, 0.1 M KNO_3
1% AMPS, 0.1 M KNO_3

Procedure:

CV and SWV

PAA

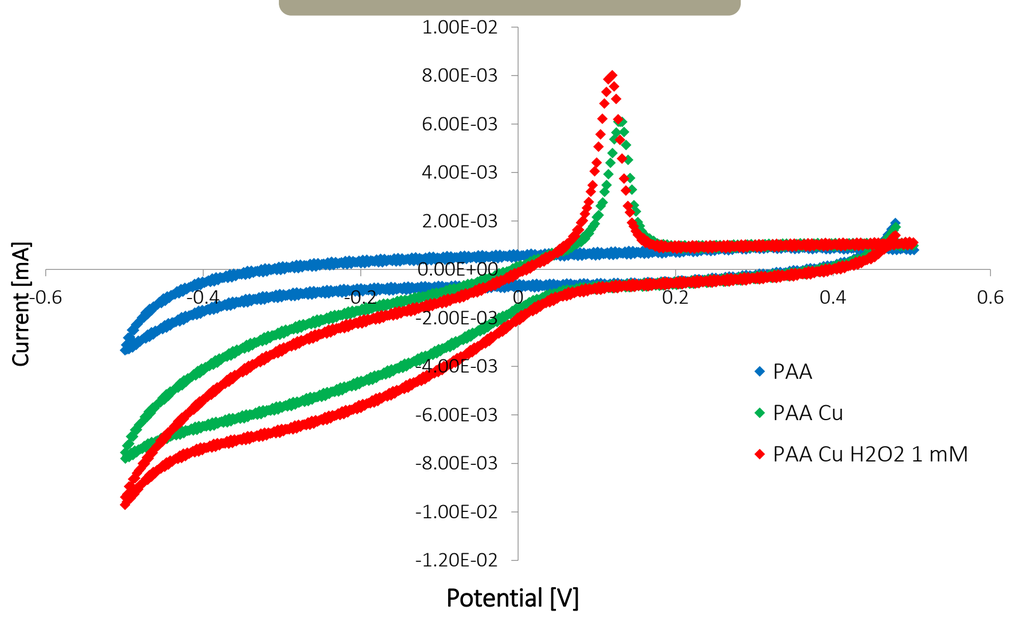

Fig. 2. Cyclic voltammograms for: 1% PAA solution (blue), PAA with Cu^{2+} (green), PAA with Cu^{2+} and 1 mM H_2O_2 (red). Scan rate: 0.05 V s^{-1}

AMPS

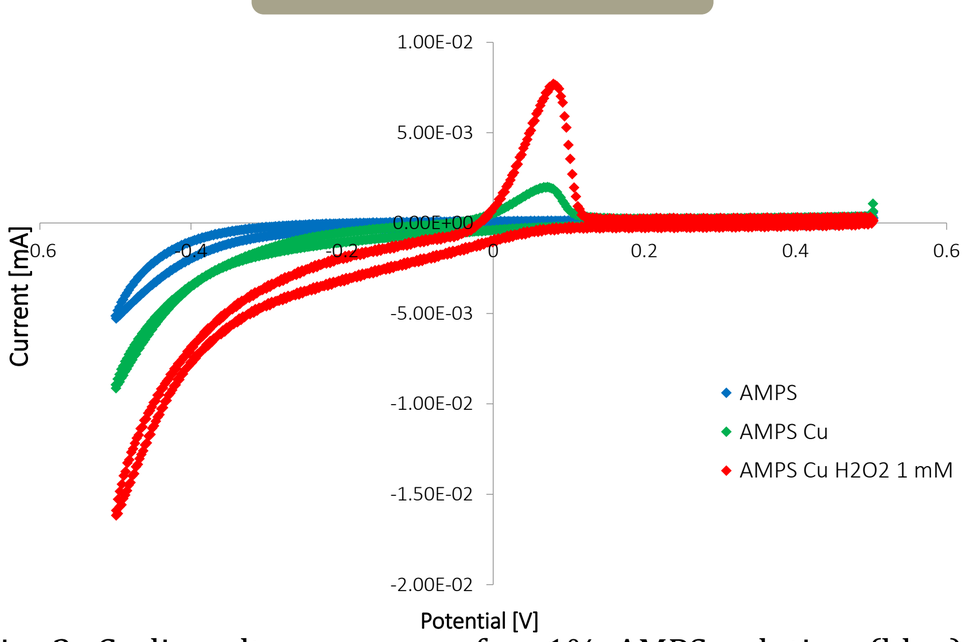

Fig. 3. Cyclic voltammograms for: 1% AMPS solution (blue), AMPS with Cu^{2+} (green), AMPS with Cu^{2+} and 1 mM H_2O_2 (red). Scan rate: 0.05 V s^{-1}

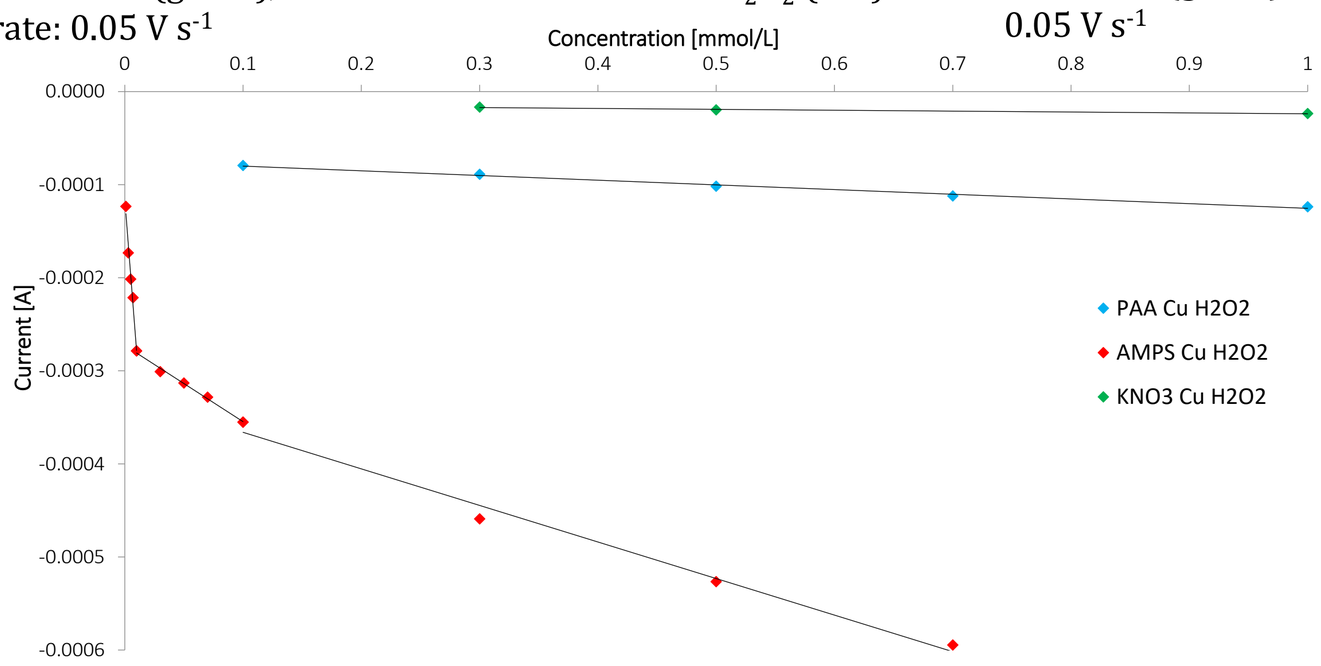

Fig. 4. Calibration curves created for aqueous solutions of supporting electrolytes with different concentrations of hydrogen peroxide with the addition of copper (II) ions. PAA - blue, AMPS - red, KNO_3 - green. Measurement conditions: step potential -0.005 V s^{-1}, amplitude 0.2 V, frequency 8 Hz.

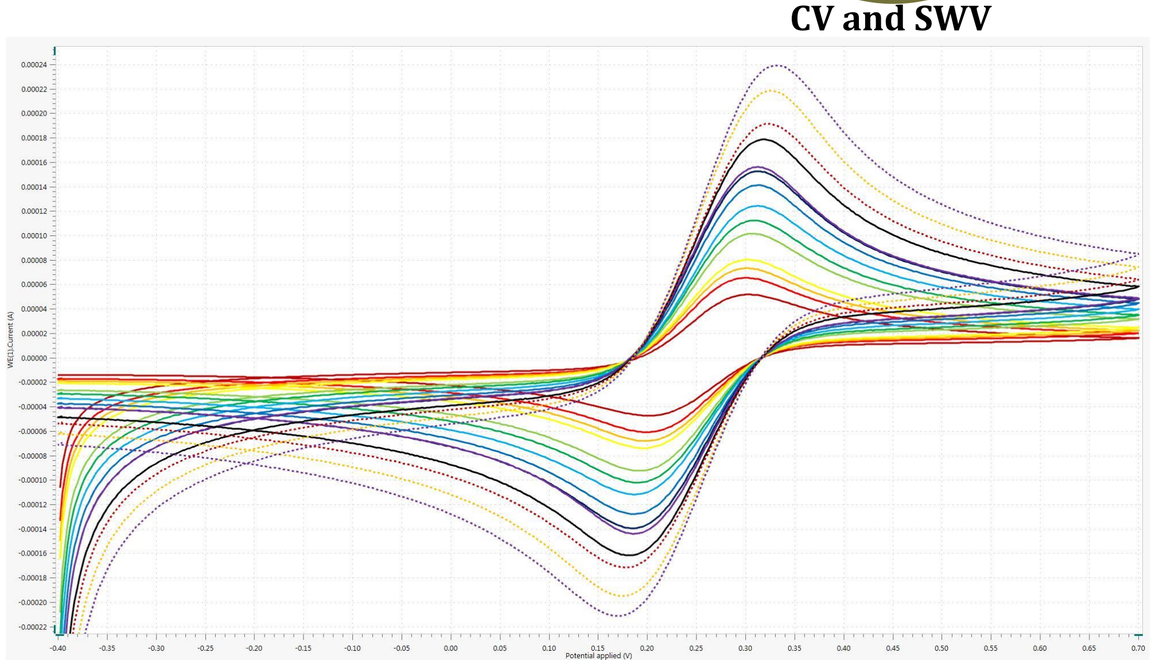

Fig 5. Cyclic voltammograms of peak height versus scanning rate for a 1% PAA aqueous solution in the presence of hexacyanoferrate (II) and (III) ions.

Fig. 6. Peak height vs. square scanning speed curves for hexacyanoferrate (II) ions in a 1% PAA solution.

CONCLUSIONS

The findings from this study strongly indicate that substituting polyacrylic acid with poly(2-acrylamido-2-methyl-1-propanesulfonic acid) as the supporting electrolyte in the hydrogen peroxide determination process leads to a remarkable reduction in the limit of detection, up to 100 times. Moreover, the exceptional properties of AMPS, particularly its high current conductivity, result in a significantly larger and faster increase in recorded current. Based on the investigated properties, it can be concluded that the determination of hydrogen peroxide in the presence of AMPS and copper(II) ions is a more efficient and effective method compared to the one with PAA presence.

While the collected results are highly promising, it is important to acknowledge that further research is necessary to fully explore and optimize the potential of this new method.