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Synthesis of effective carbon-based composite materials as electrocatalysts for electrochemical reactions

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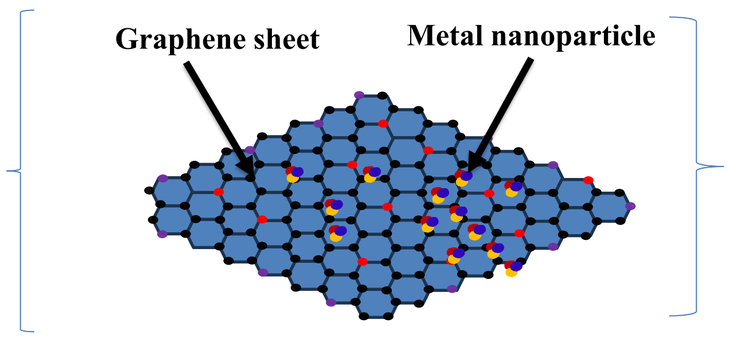
INTRODUCTION & AIM

- Significant interest has been given to the development of multifunctional electrocatalysts based on metal nanoparticles and graphitic carbon composite.
- We reported on the synthesis of heteroatom-doped graphitic carbon nanofibers using the chemical vapor deposition technique for applications in catalytic reactions, including oxygen reduction, evolution, and hydrogen generation [1-4].
- carbon-based composite materials as electrocatalysts for electrochemical reactions were significantly explored **for hydrogen fuel cell, metal-air battery, Water electrolysis, and other electrochemical devices.**



Electrocatalytic reactions

◆ **Oxygen reduction reaction (ORR)**
$O_2+4H^++4e^- \rightarrow 2H_2O$

◆ **Oxygen evolution reaction (OER)**
$2H_2O \rightarrow O_2+4H^-+4e^-$

◆ **Hydrogen evolution reaction (HER)**
$2H^++2e^- \rightarrow H_2$

Schematic metal nanoparticle supported on graphene sheet as electrocatalyst for ORR, OER and HER reactions

Aim of the research:

1. Develop novel and effective catalyst for electrochemical reaction based on composite materials.
2. Use of graphene-based materials as support for electrocatalyst and electrochemical reactions.
3. Achieving multifunctional properties of electrocatalyst for efficient electrocatalysis in ORR, OER and HER electrochemical reactions.

METHOD

◆ **Synthesis method of cobalt oxide (CoO) and graphene oxide (GO) composite**

Cobalt chloride, a reducing agent, and graphene oxide were mixed and heated to form a reduction process that simultaneously oxidized the cobalt chloride and reduced the graphene oxide, resulting in the cobalt oxide being supported on the graphene oxide.
The experimental method is as follows:
1. Graphene oxide (200 mg) was mixed in distilled water (50 ml) and ultrasonicated for 30 minutes.
2. Cobalt chloride (5 mM) and citric acid (4 mM) were mixed with distilled water (50 ml) and added to the above solution.
3. Stirred at 950 rpm for 1 hour.
4. The solution was heated at 150° C for 20 minutes
5. The obtained sample was heated at 400° C for 1 hour in argon gas atmosphere.

◆ **Synthesis method of MoO_x-MoS_x and graphene oxide (GO) composite**

Ammonium trathiomolybdate was used for synthesis of MoO_x-MoS_x/GO composite in hydrothermal process in presence of urea as reducing agent. A solution was prepared by dissolving the Ammonium trathiomolybdate and urea in 100ml DI water. The solution was mixed at 950 rpm with a stirrer, and the sample was moved to Teflon-lined autoclave. The hydrothermal reaction was performed at 160 ℃ for 24 hours. In the following the experimental process in shown.

Hydrothermal Synthesis of MoO_x-MoS_x/GO composite electrocatalysts

1. **Ammonium trathiomolybdate**
2. **Urea (As reducing agent)**

→ **Dissolved in DIwater (100 ml)**

→ **Mixed at 950 rpm with a stirrer**

→ **Move to Teflon-lined autoclave and heated at 160 ℃ for 24h**

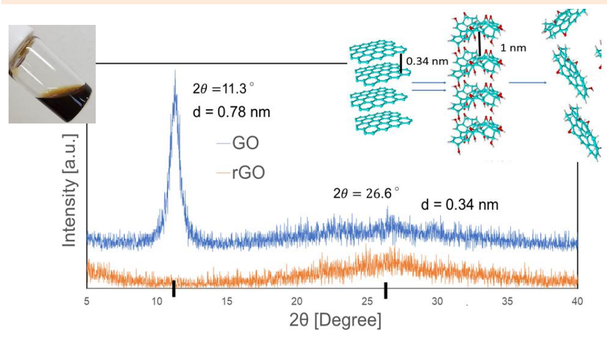
→ **Filtered and wash with DI water , and dry in vacuum oven**

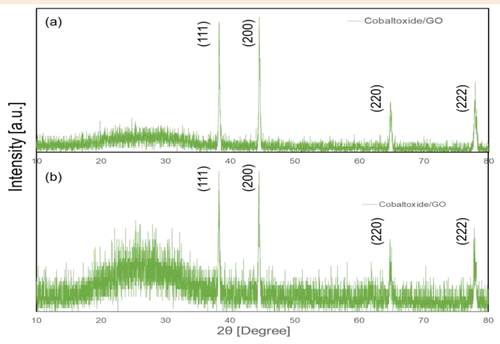
◆ **Analysis methods and electrochemical analysis process**

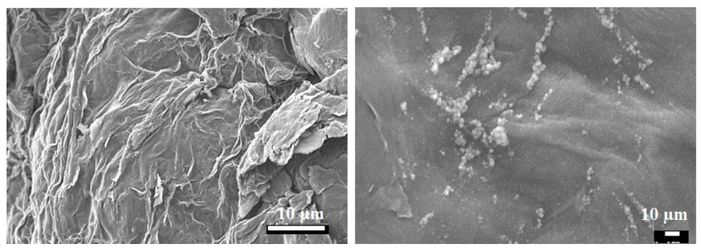
- The synthesised materials were analysed by X-ray diffraction analysis (XRD), scanning electron microscope (SEM) and X-ray photoelectron spectroscopy (XPS) to investigate the structural and morphological properties.
- Electrochemical studies of the materials were performed by Metrohm Autolab potentiostat/galvanostat using glassy carbon electrode.

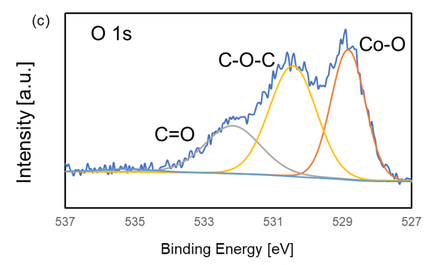
RESULTS & DISCUSSION

XRD, SEM and XPS analysis of the synthesized composite of cobalt oxide (CoO) and graphene oxide (GO) used for catalytic reactions



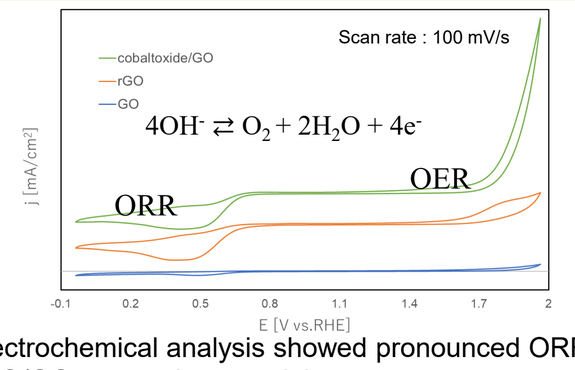


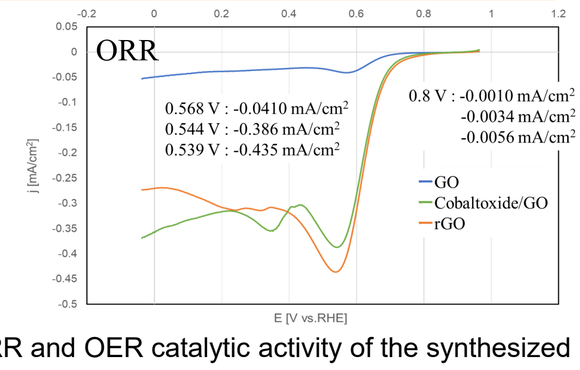




XRD, SEM and XPS analysis showed well-dispersed CoO nanoparticles in the rGO sheets

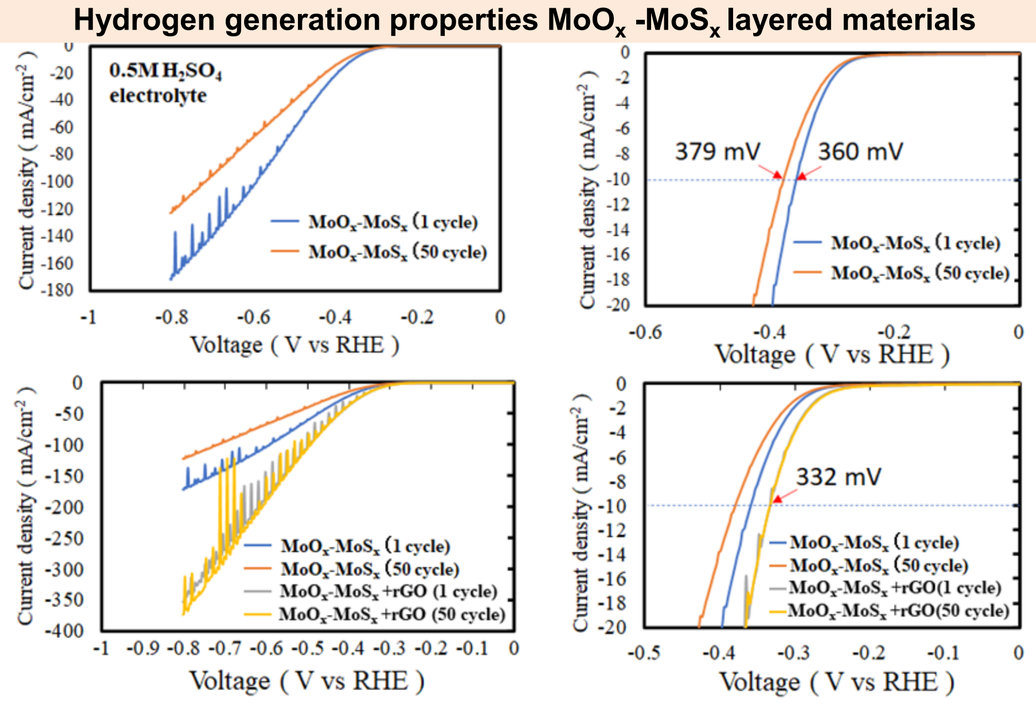
Chemical properties of CoO-rGO: Cyclic voltammetry (CV)





Electrochemical analysis showed pronounced ORR and OER catalytic activity of the synthesized CoO/GO composite materials

Hydrogen generation properties MoO_x -MoS_x layered materials



- ✓ Obtained excellent current density for hydrogen generation for the synthesized MoOx-MoSx with rGO.
- ✓ The stability of MoOx-MoSx catalyst enhance significantly with addition of rGO, considering better electron conduction as well improving releases of hydrogen gas from the electrode surfaces.

CONCLUSION

- This study reveals that the GO-based material serves as an excellent host material for CoO and MoO_x/MoSx-based composites, enabling the design of effective electrocatalysts for oxygen reduction (ORR), evolution (OER), and hydrogen generation (HER).
- Thus, this research revealed the synthesis of effective composite electrocatalysts for green energy generation and storage device applications.

FUTURE WORK / REFERENCES

1. Adv. Energy Mater., vol. 5, pp. 1500658 (2015).
2. ChemistrySelect, vol. 7, issue 26, pp. e202201386, (2022).
3. J. Phys. Chem. C, vol. 125, issue 45, pp. 25197-25206, (2021).
4. ChemistrySelect, vol. 6, pp. 4867-4873, (2021).