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## **Title: MgO@ $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> Based Hydroelectric Cell for Efficient Green Energy Generation**

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## Author Questionnaire

**1.** We have marked your project as author-provided footage, meaning you film the video yourself and provide JoVE with the footage to edit. JoVE will not send the videographer. Please confirm that this is correct.

✓ Correct

**2. Microscopy:** Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

**3. Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **No**

**4. Proposed filming date:** To help JoVE process and publish your video in a timely manner, please indicate the proposed date that your group will film here: **02/1/2026**

When you are ready to submit your video files, please contact our Content Manager, [Utkarsh Khare](#).

### Current Protocol Length

Number of Steps: 17

Number of Shots: 43

# Introduction

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**Authors:** Please note that the questions will not appear on screen. Please answer in **stand-alone full sentence with sufficient context**.

## INTRODUCTION:

**NOTE:** Use the timestamps given below for intro and conclusion

**REQUIRED:** What is the scope of your research? What questions are you trying to answer?

- 1.1. Priyambada Sahoo: The scope of our research is developing  $\text{MgO}@-\text{Fe}_2\text{O}_3$  hydroelectric cells and understanding nanocomposite-enhanced water adsorption and charge transport mechanisms.

1.1.1. Use V\_1.1-1.2\_Introduction\_R2 :00:00-00:10

**What are the most recent developments in your field of research?**

- 1.2. Priyambada Sahoo: Recent research explores defect-associated ferrites and metal-oxide and metal-organic framework materials beyond simple oxides to enhance water-driven energy generation.

1.2.1. V\_1.1-1.2\_Introduction\_R2 00:47-01:05.

## CONCLUSION:

**What significant findings have you established in your field?**

- 1.3. Priyambada Sahoo: We established a high-performance  $\text{MgO}@-\text{Fe}_2\text{O}_3$  hydroelectric cell where optimized ferrite incorporation enhances defects, hydrophilicity, active sites, and doubles power output.

1.3.1. V\_1.3-1.4-1.5\_Conclusion\_R2 00:00-00:20.

**What research gap are you addressing with your protocol?**

- 1.4. Priyambada Sahoo: Our protocol addresses the lack of a simple, scalable, and reproducible fabrication method for high-performance hydroelectric cells with controlled defect chemistry.

1.4.1. V\_1.3-1.4-1.5\_Conclusion\_R2 00:20-00:44.

**What advantage does your protocol offer compared to other techniques?**

- 1.5. **Priyambada Sahoo:** ~~Our protocol offers a low-cost, scalable solid-state fabrication approach enabling precise defect tuning and reproducible hydroelectric performance without external bias, light, or complex equipment.~~
- 1.5.1. ~~INTERVIEW: Named talent says the statement above in an interview style shot, looking slightly off-camera.~~

## Protocol

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### 2. Synthesis of Nanostructured Porous Magnesium Oxide–Iron(III) Oxide ( $\text{MgO}@ \alpha\text{-Fe}_2\text{O}_3$ ) Composites via Ball Milling and Calcination

**Demonstrator:** Priyambada Sahoo

- 2.1. To begin, collect magnesium oxide powder and alpha iron(III) (*three*) oxide powder along with a ball miller, zirconia milling balls, and a milling bowl [1]. Weigh 5 grams of magnesium oxide [2] and add 2 percent, 5 percent, or 10 percent alpha iron(III) oxide, by weight, into a 50-milliliter milling bowl [3]. Add zirconia milling balls maintaining a ball-to-powder ratio of 4 to 1 [4].
  - 2.1.1. Talent arranging magnesium oxide, alpha iron(III) oxide, milling bowl, and zirconia balls on the workbench.
  - 2.1.2. Talent weighing 5 g magnesium oxide.
  - 2.1.3. Talent adding alpha iron(III) oxide powders to MgO and transferring them into the milling bowl.
  - 2.1.4. Talent adding zirconia balls into the milling bowl.
- 2.2. Now, place the loaded bowl into the ball miller [1]. Set the ball rotation speed to 300 revolutions per minute and the bowl rotation speed to 600 revolutions per minute [2]. Ball mill the precursor powders continuously for 24 hours to ensure homogeneous mixing [3].
  - 2.2.1. Talent placing the milling bowl into the ball miller.
  - 2.2.2. Shot of the ball miller control panel showing the rotation speeds being set.
  - 2.2.3. Shot of the milling process.
- 2.3. Collect the ball-milled powder from the bowl after milling [1] and transfer the powder into a crucible [2]. Place the crucible inside a box furnace and calcine at 600 degrees Celsius for 4 hours to obtain nanostructured porous material [3].
  - 2.3.1. Talent collecting the ball-milled powder into a container.
  - 2.3.2. Talent transferring the powder into a furnace-compatible crucible.
  - 2.3.3. Talent placing the crucible inside the box furnace and closing the furnace door.
- 2.4. Observe the color change of the calcined powder from white to dark red with increasing

alpha iron(III) oxide weight percentage [1]. Label the prepared nanocomposites as MF0 (*M-F-Zero*), MF2 (*M-F-Two*), MF5 (*M-F-Five*), and MF10 (*M-F-Ten*) according to their alpha iron(III) oxide content [2].

2.4.1. Shot of differently colored powders after calcination.

2.4.2. Talent labeling sample containers as MF0, MF2, MF5, and MF10.

### **3. Fabrication and Assembly of MgO@ $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> Hydroelectric Cell Devices**

3.1. To fabricate the hydroelectric cell device, transfer 1.8 grams of each calcined nanocomposite powder into a mortar [1]. Add 4 drops of 2% polyvinyl alcohol solution [2]. With a pestle, grind the mixture until a dry and homogeneous powder is obtained [3].

3.1.1. Talent weighing the calcined powder into a mortar.

3.1.2. Talent adding drops of polyvinyl alcohol solution to the powder.

3.1.3. Talent grinding the mixture using a pestle.

3.2. Transfer the prepared powder into a square-shaped mold [1]. Using a hydraulic press, compress the powder into a 2.2 by 2.2 centimeter square pellet [2]. Then remove the pellet carefully from the mold [3].

3.2.1. Talent filling the pellet mold with powder.

3.2.2. Talent operating the hydraulic press to form the pellet.

3.2.3. Talent removing the formed pellet from the mold.

3.3. Sinter the pellets at 650 degrees Celsius for 4 hours in a box furnace to remove polyvinyl alcohol and obtain compact pellets [1]. Remove the pellets and allow them to cool to room temperature [2].

3.3.1. Talent transferring the pellets into the box furnace

3.3.2. Talent removing the sintered pellets from the furnace.

3.4. Next, apply Araldite epoxy onto a zinc sheet to serve as the anode [1]. Attach the sintered pellet firmly onto the zinc sheet [2] and place the assembled structure on a hot plate set to 70 degrees Celsius to improve adhesion [3].

3.4.1. Talent applying epoxy onto the zinc sheet.

3.4.2. Talent positioning the pellet onto the zinc sheet.

3.4.3. Talent placing the device on a hot plate.

3.5. Using silver paint, apply a comb-pattern electrode on the top surface of the pellet to form the cathode for maximum current collection [1]. Characterize the structural, surface, and chemical properties of the nanocomposites to understand their composition and behavior [2].

3.5.1. Talent painting a comb-pattern electrode using silver paste.

Added shot: Reuse

## Results

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### 4. Results

- 4.1. X-ray diffraction analysis of pristine and nanocomposites confirmed the phase purity of the nanocomposites, with diffraction peaks [1] corresponding exclusively to cubic magnesium oxide [2] and trigonal alpha iron(III) oxide phases, and no impurity peaks detected [3].
  - 4.1.1. LAB MEDIA: Figure 3A
  - 4.1.2. LAB MEDIA: Figure 3A. *Video editor: Please highlight all the peaks labeled "MgO" denoted by a black heart symbol*
  - 4.1.3. LAB MEDIA: Figure 3A. *Video editor: Please highlight all the peaks labeled " $\alpha\text{Fe}_2\text{O}_3$ " denoted by a red clover symbol*
- 4.2. The average crystallite size decreased from 24.05 nanometers in MF0 to 19.18 nanometers in MF10 [1], while lattice strain increased with increasing alpha iron(III) oxide content [2].
  - 4.2.1. LAB MEDIA: Figure 3B. *Video editor: Please highlight the downward trend in the black curve*
  - 4.2.2. LAB MEDIA: Figure 3B. *Video editor: Please highlight the upward trend in the blue curve*
- 4.3. Fourier transform infrared spectroscopy revealed that with an increase in the content of alpha iron(III) oxide in magnesium oxide, the height of the absorption bands of the surface-adsorbed hydroxyl group between 1400 to 1800 inverse centimeters increased prominently, substantiating the suitability of the nanocomposite for hydroelectric cell applications [1].
  - 4.3.1. LAB MEDIA: Figure 4A. *Video editor: Highlight the curves from bottom to top sequentially* **NOTE: Use updated figure 4A from the website**
  - 4.3.2. LAB MEDIA: Figure 4A. *Video editor: Highlight the area between 1400 to 2000 mark on the X axis in all curves from bottom to top sequentially*
- 4.4. Raman spectroscopy of the samples confirmed the presence of all 5 Raman vibrational modes of alpha iron(III) oxide in MF2, MF5, and MF10 samples [1] and the MF10 sample showed relatively more prominent peaks [2].

4.4.1. LAB MEDIA: Figure 4B. *Video editor: Highlight the area between 200-600 mark on X-axis for curves MF2 MF5 MF10*

4.4.2. LAB MEDIA: Figure 4B. *Video editor: Please sequentially highlight A1g, Eg, Eg, A1g, and Eg PEAKS in curve MF10*

4.5. Field Emission Scanning Electron Microscopy analysis showed highly agglomerated spherical-shaped nanoparticles in all samples along with nanoporous structures [1]. The presence of Magnesium, Oxygen, and iron with their atomic and weight percentages was determined using Energy Dispersive X-ray Analysis in MF0 and MF10 samples [2]. Brunauer–Emmett–Teller analysis showed reduced average pore radius and volume from MF0 to MF10 [3].

4.5.1. LAB MEDIA: Figure 5 ABCD

4.5.2. LAB MEDIA: Figure 5 E and F *Video Editor: Please highlight E and F sequentially when Vo says MF0 and MF10*

4.5.3. LAB MEDIA: Table 2 *Video Editor: Please highlight the column “Average Pore Radius (nm)” and “Average pore volume” sequentially from MF0 to MF10 rows*

4.6. X-ray photoelectron spectroscopy confirmed the presence and chemical states of magnesium, oxygen, and iron in the nanocomposites [1] through Mg 1s (*Magnesium-1-S*), Mg 2p (*Magnesium-2-P*) [2], O 1s (*Oxygen-1-S*) [3] and Fe 2p (*Iron-2-P*) core-level spectra [4].

4.6.1. LAB MEDIA: Figure 7A–I.

4.6.2. LAB MEDIA: Figure 7A–I. *Video editor: Please sequentially highlight A-B*

4.6.3. LAB MEDIA: Figure 7A–I. *Video editor: Please sequentially highlight C to F*

4.6.4. LAB MEDIA: Figure 7A–I. *Video editor: Please sequentially highlight G to I*

## 1. Nanostructured

Pronunciation link: No confirmed link found

IPA: /ˌnænoʊˈstrʌktʃərd/

Phonetic Spelling: nan·oh·struk·cherd

## 2. Magnesium

Pronunciation link: [<https://www.merriam-webster.com/dictionary/magnesium>](<https://www.merriam-webster.com/dictionary/magnesium>)

IPA: /ˈmæɡˌniːziəm, -zəm/

Phonetic Spelling: mag·nee·zee·uhm, mag·nee·zhuhm

3. Oxide

Pronunciation link: [<https://www.merriam-webster.com/dictionary/oxide>](<https://www.merriam-webster.com/dictionary/oxide>)

IPA: /'ɒk.sɪd/

Phonetic Spelling: ok·side

4. Zirconia

Pronunciation link: [<https://www.merriam-webster.com/dictionary/zirconia>](<https://www.merriam-webster.com/dictionary/zirconia>)

IPA: /zɜːˈkɒniə/

Phonetic Spelling: zur·koh·nee·uh

5. Calcination

Pronunciation link: [<https://www.merriam-webster.com/dictionary/calcination>](<https://www.merriam-webster.com/dictionary/calcination>)

IPA: /ˌkælsəˈneɪʃən/

Phonetic Spelling: kal·suh·nay·shuhn

6. Hydroelectric

Pronunciation link: [<https://www.merriam-webster.com/dictionary/hydroelectric>](<https://www.merriam-webster.com/dictionary/hydroelectric>)

IPA: /ˌhaɪdrouˈlektɹɪk/

Phonetic Spelling: hy·droh·ih·lek·trik

7. Polyvinyl alcohol

Pronunciation link: [<https://www.merriam-webster.com/dictionary/polyvinylalcohol>](<https://www.merriam-webster.com/dictionary/polyvinylalcohol>)

IPA: /ˌpɒliˌvaɪnəl ˈælkəˌhɒl/

Phonetic Spelling: pol·ee·vy·nuhl al·kuh·hawl

8. Anode

Pronunciation link: [<https://www.merriam-webster.com/dictionary/anode>](<https://www.merriam-webster.com/dictionary/anode>)

IPA: /'æ.nəʊd/

Phonetic Spelling: an·ohd

9. Cathode

Pronunciation link: [<https://www.merriam-webster.com/dictionary/cathode>](<https://www.merriam-webster.com/dictionary/cathode>)

IPA: /'kæθ.əʊd/

Phonetic Spelling: kath·ohd

10. Diffraction

Pronunciation link: [<https://www.merriam-webster.com/dictionary/diffraction>](<https://www.merriam-webster.com/dictionary/diffraction>)

IPA: /dɪˈfrækʃən/

Phonetic Spelling: dih·frak·shuhn

11. Crystallite

Pronunciation link: [<https://www.merriam-webster.com/dictionary/crystallite>](<https://www.merriam-webster.com/dictionary/crystallite>)

IPA: /ˈkrɪstəˌlaɪt/

Phonetic Spelling: kris·tuh·lyte

12. Hydroxyl

Pronunciation link: [<https://www.merriam-webster.com/dictionary/hydroxyl>](<https://www.merriam-webster.com/dictionary/hydroxyl>)

IPA: /haɪˈdrɒksəl/

Phonetic Spelling: hy·drok·suhl

13. Spectroscopy

Pronunciation link: [<https://www.merriam-webster.com/dictionary/spectroscopy>](<https://www.merriam-webster.com/dictionary/spectroscopy>)

IPA: /spekˈtrɒskəpi/

Phonetic Spelling: spek·tros·kuh·pee

14. Photoelectron

Pronunciation link: [<https://www.merriam-webster.com/dictionary/photoelectron>](<https://www.merriam-webster.com/dictionary/photoelectron>)

IPA: /ˌfoʊtoʊˈlɛkˌtrɒn/

Phonetic Spelling: foh·toh·ih·lek·tron

15. Epoxy

Pronunciation link: [<https://www.merriam-webster.com/dictionary/epoxy>](<https://www.merriam-webster.com/dictionary/epoxy>)

IPA: /ɪˈpɒksi/

Phonetic Spelling: ih·pok·see

16. Sinter

Pronunciation link: [<https://www.merriam-webster.com/dictionary/sinter>](<https://www.merriam-webster.com/dictionary/sinter>)

IPA: /ˈsɪntər/

Phonetic Spelling: sin·ter