Development of Sustainable TiO_2(B)/MOFs Nanocomposites as an Anode Material in Lithium-Ion Batteries

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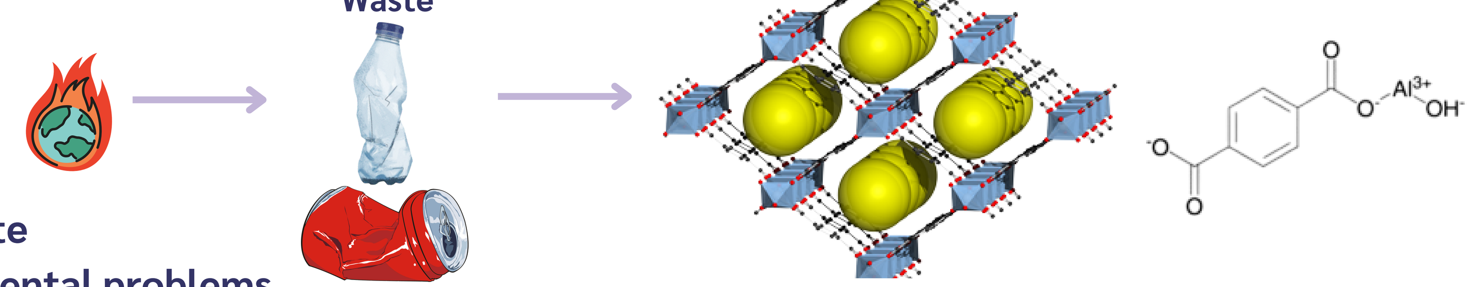
Abstract

This study explores the development of TiO_2(B)/MOFs composites as a promising anode material for lithium-ion batteries (LIBs). The novel aspect of this research is the synthesis of metal-organic frameworks (MOFs), particularly MIL-53(Al), from waste materials. These MOFs are then integrated with bronze-phase Titanium dioxide (TiO_2(B)), which is known for its enhanced charge transfer properties and excellent structural stability. This combination results in significant improvements in the electrochemical performance of MOFs when used in battery applications.The synthesis of MIL-53(Al) involved utilizing polyethylene terephthalate (PET) derived from plastic bottles to produce terephthalic acid (TPA). This TPA was then reacted with aluminum (Al) extracted from aluminum cans to form the final MOFs product. On the other hand, TiO_2(B) was synthesized through a hydrothermal process and ion exchange, followed by calcination at 450°C for five hours. The TiO_2(B)/MOFs composites were synthesized via a physical method, in which the materials were mechanically mixed in a mortar for 30 minutes. Different weight ratios of MOF: TiO_2(B) were tested—25:75, 50:50, and 75:25—to evaluate their impact on the performance of the final composite. The composite morphology was characterized using scanning electron microscopy (SEM), revealing that the MOF particles were large and angular, with TiO_2(B) nanorods distributed across their surface. X-ray diffraction (XRD) confirmed that the synthesized TiO_2 corresponded to the bronze-phase structure. These composites were then tested in coin cell batteries, where electrochemical testing demonstrated that the composite with a 75:25 MOFs: TiO_2(B) weight ratio showed the best performance. This composite exhibited the highest cycling stability, achieving a specific capacity of 136.06 mAh/g at a current density of 100 mA/g after 50 cycles. Overall, this study indicates that increasing the TiO_2(B) content in TiO_2(B)/MOFs composites enhances battery performance higher than pure MOFs. This suggests that TiO_2(B)-MOFs composites, due to their stable framework and high porosity, are a promising candidate for next-generation anode materials in lithium-ion batteries.

Introduction

MOFs

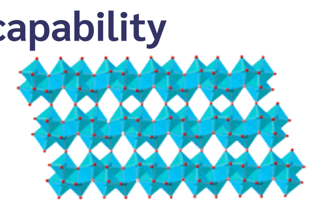
Advantages
- New material
- Low cost
- Made from waste
- Solve environmental problems



Aluminum terephthalate, $C_8H_5AlO_5$, MIL-53 (Al)

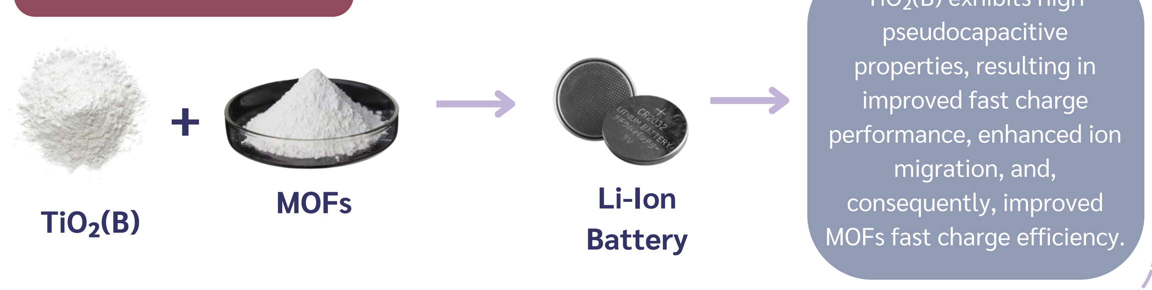
TiO_2(B)

Advantages
- Fast charging capability
- High stability
- Long cycle life



Titanium dioxide bronze phase, TiO_2(B)

This research

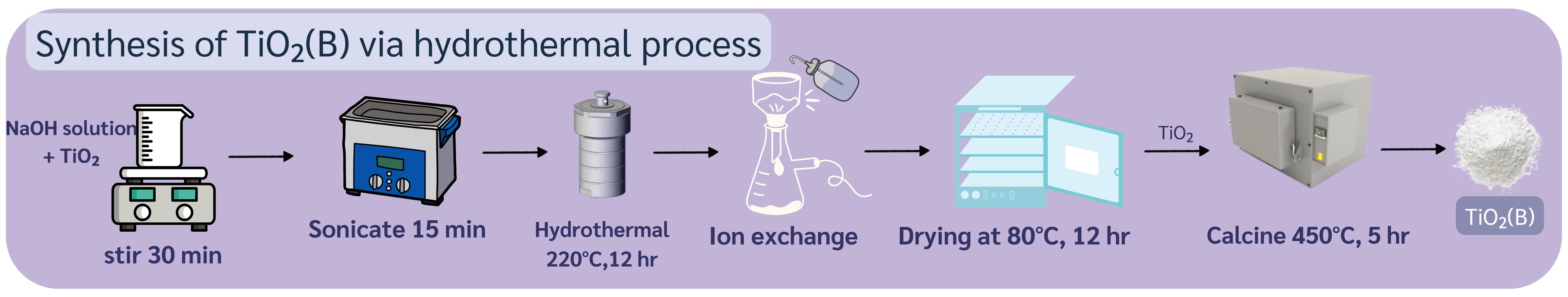


Objective

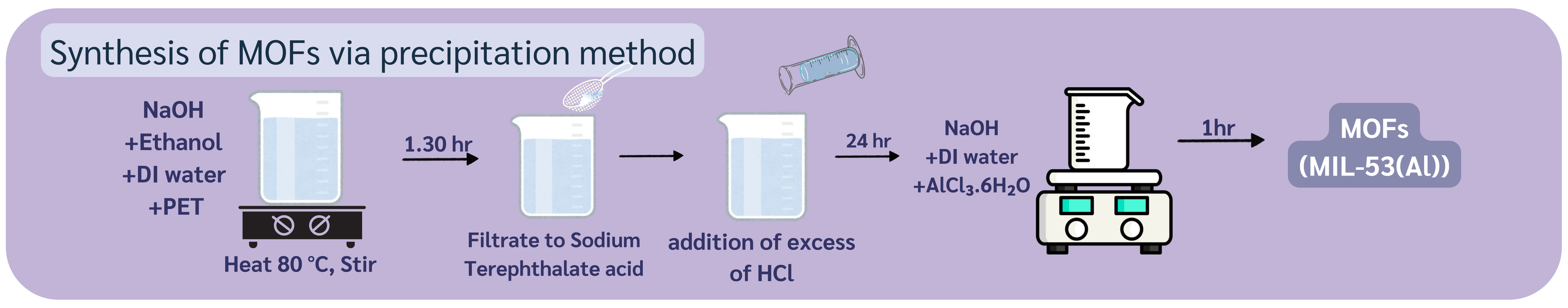
1. To synthesize TiO_2(B) / MOFs composites anode material using physical methods.
2. To characterize TiO_2(B) / MOFs composites anode material
3. To study the influence of different ratios between MOFs and TiO_2(B) on the battery performance.

Experiment

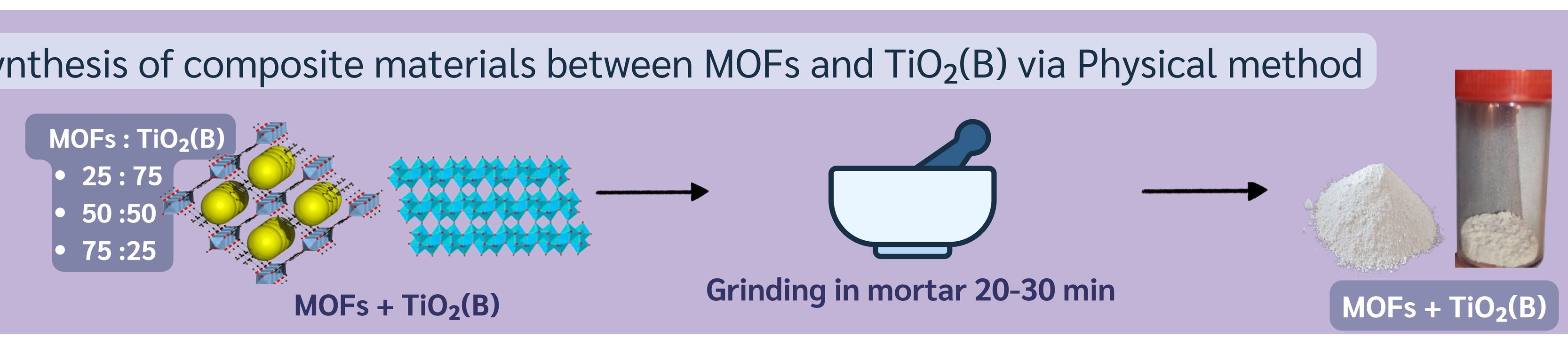
Synthesis of TiO_2(B) via hydrothermal process



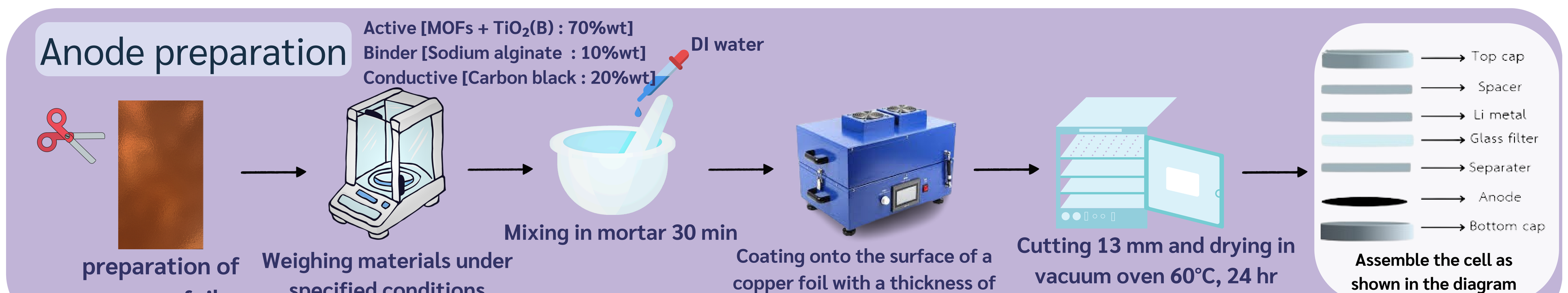
Synthesis of MOFs via precipitation method



Synthesis of composite materials between MOFs and TiO_2(B) via Physical method

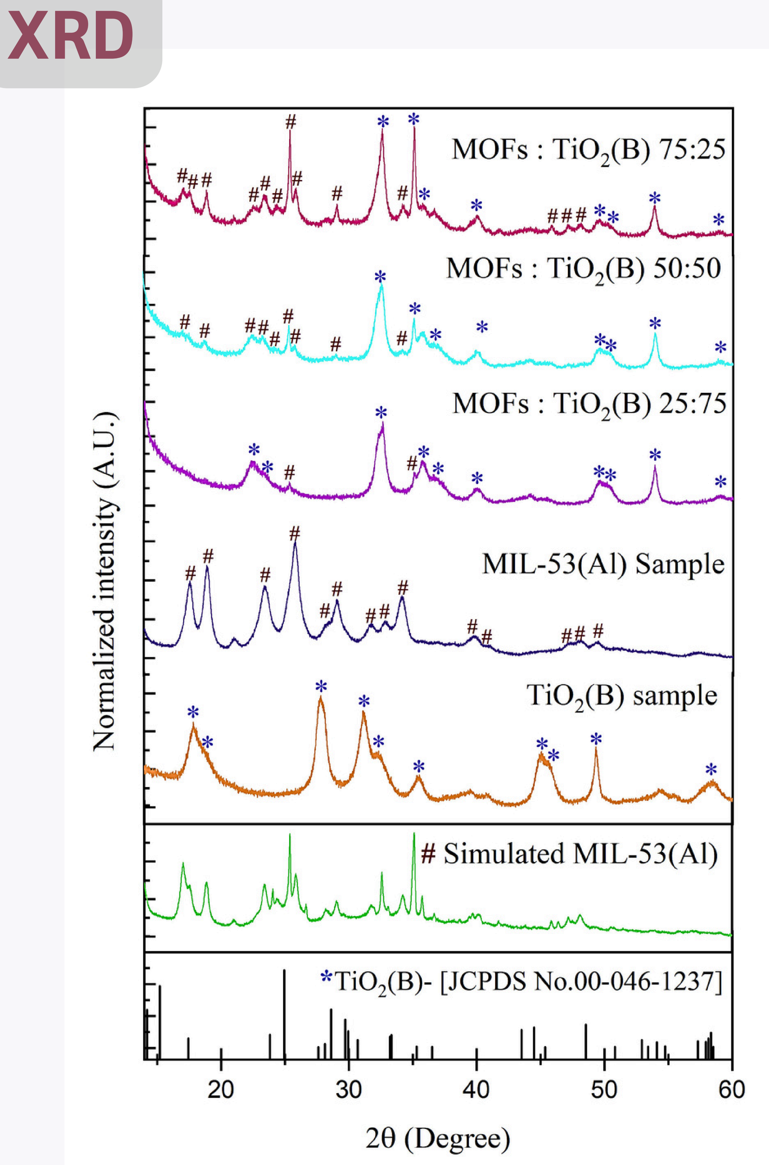


Anode preparation

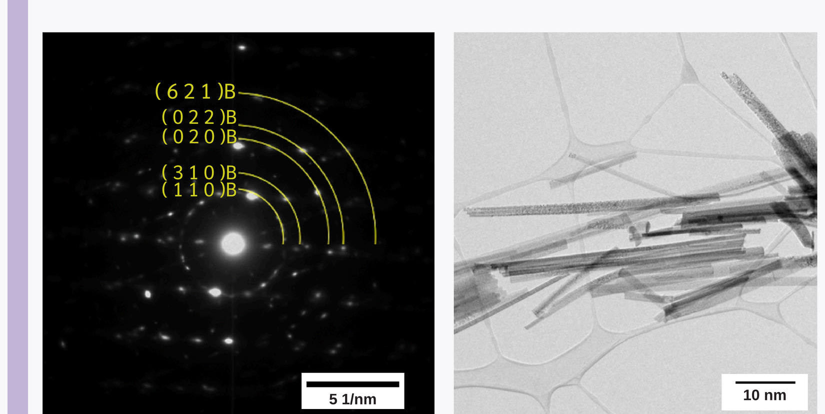


Result & discussion

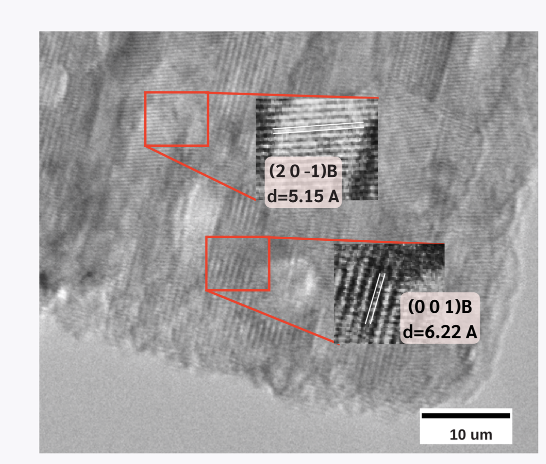
XRD



TEM of TiO_2(B)

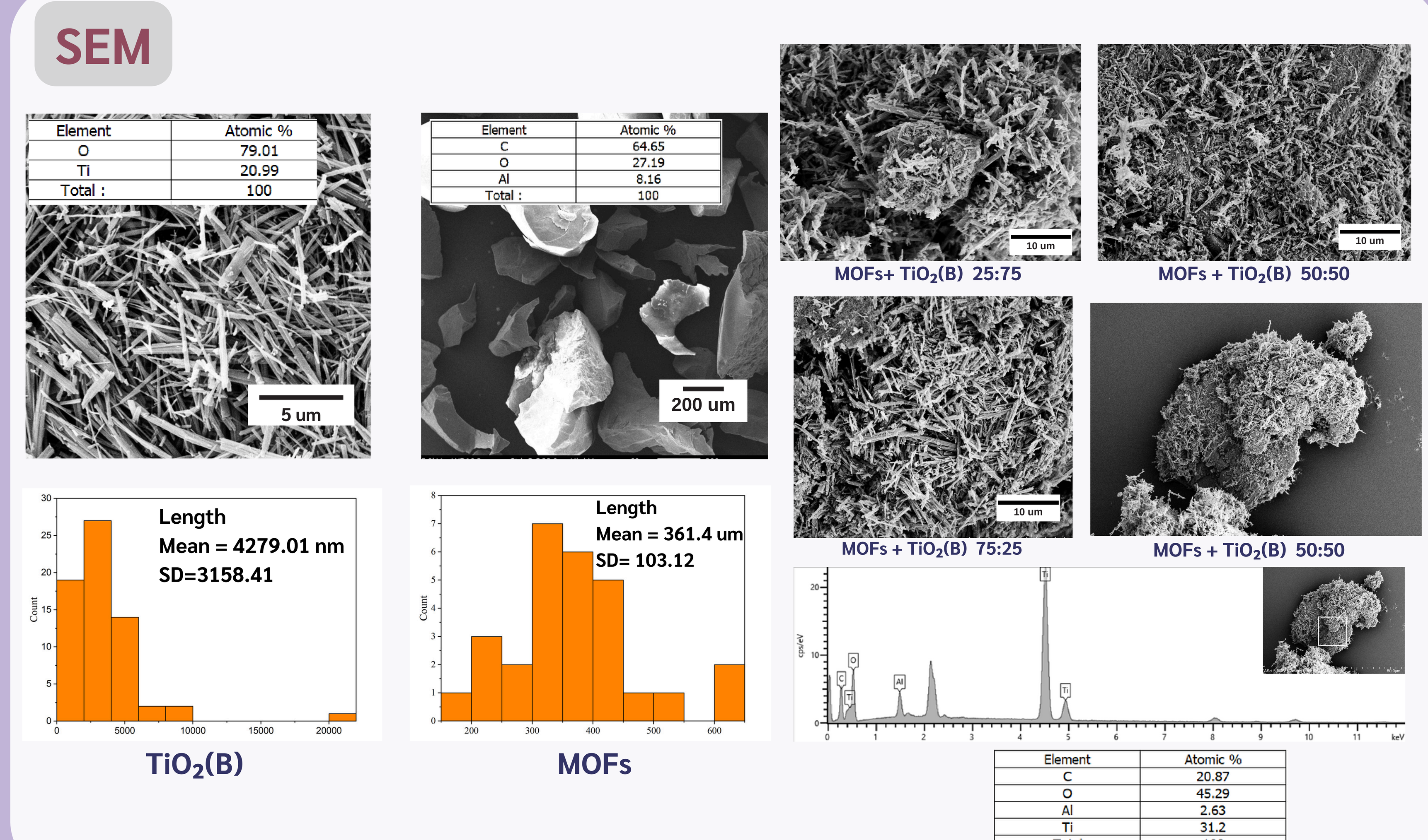


(SEAD) of TiO_2(B) Bright field image of TiO_2(B)

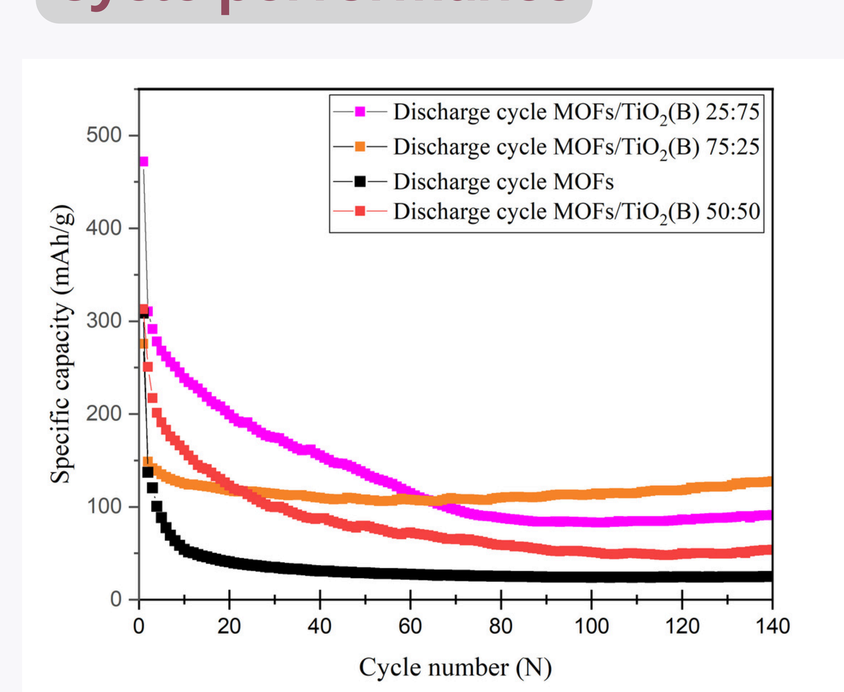


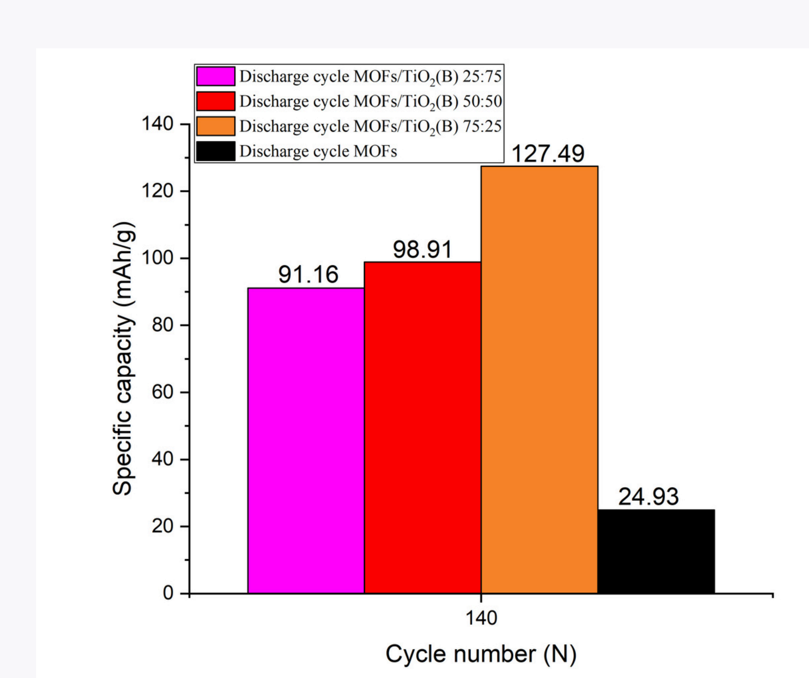
High resolution transmission electron microscopy (HRTEM) of TiO_2(B)

SEM



Cycle performance





Conclusion

"This research successfully synthesized MOFs via the precipitation method and TiO_2(B) via the hydrothermal method. X-ray diffraction (XRD) analysis was employed to confirm the crystal structure, validating that the synthesized TiO_2 corresponded to the bronze phase. The MOFs/TiO_2(B) composite was successfully synthesized using a physical method, with the morphology of TiO_2(B) nanorods, while the MOFs exhibited large particles. In lithium-ion battery performance testing, the MOFs: TiO_2(B) ratio of 75:25 wt.% demonstrated the highest cycling stability, achieving a specific capacity of 136.06 mAh/g at a current density of 100 mA/g after 50 cycles. However, after 140 cycles, the specific capacity of the MOFs: TiO_2(B) ratio of 75:25 wt.% was found to be the highest, reaching 127.49 mAh/g at a current density of 100 mA/g. This study suggests that increasing the TiO_2(B) content enhances battery performance due to its stable framework and high porosity, which can improve certain properties of MOFs. This makes it a promising candidate for next-generation anode materials in lithium-ion batteries."

Acknowledge

I would like to thank Asst.Prof. Dr.Yothin Chimupla, Mr.Korawith Pimta and Ms.Saitharn Limsakul for their ideal and experimental support and kindness while I started this project in PTEM Laboratory.

Reference :

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