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论文题目：Photocatalytic Conversion of Polylactic Acid over
Oxygen-Vacancy-Rich Bismuth Oxychloride

Photocatalytic Conversion of Polylactic Acid over Oxygen-Vacancy-Rich Bismuth Oxychloride

Ziye Zhang

Abstract

PLA is widely introduced as an environmentally friendly material and has been adopted in place of conventional petroleum-derived plastics, but its degradation process is slow under natural environmental conditions. This study focused on the photocatalytic conversion of polylactic acid (PLA) over Bi_2O_3 , BiOCl , and oxygen-vacancy-rich BiOCl (BiOCl-Ov). The effects of catalyst compositions, reaction atmosphere, electrolytes, and irradiation time have been investigated. For catalyst characterization, we used X-ray diffraction (XRD), Scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and UV-vis spectroscopy. The XPS and optical measurements supported the presence of oxygen-vacancy-related sites in BiOCl-Ov ; its estimated band gap was 3.29 eV, compared with 3.41 eV for BiOCl . In 0.5 M NaCl in air for 3 hours, lactic acid yield with BiOCl-Ov was $2670.8 \mu\text{mol g}^{-1}$, compared with $911.4 \mu\text{mol g}^{-1}$ for BiOCl . Lactic acid generation with BiOCl-Ov increased to $4426.3 \mu\text{mol g}^{-1}$ in an Ar atmosphere, and CO_2 formation decreased. The replacement of NaCl with Na_2SO_4 in an Ar atmosphere resulted in a reduction of lactic acid generation to $457.0 \mu\text{mol g}^{-1}$, showing that electrolyte composition strongly affected product distribution. Increasing the irradiation time from 3 to 12 h reduced the amount of lactic acid produced while increasing the yields of acetic acid, acetaldehyde, and CO_2 . In summary, these findings demonstrate that the BiOCl-Ov material can favor lactic acid accumulation from PLA under the conditions tested in this work. The catalyst, atmosphere, electrolyte, and reaction time should therefore be considered together when evaluating this photocatalytic system.

Keywords: polylactic acid; photocatalytic conversion; bismuth oxychloride; oxygen vacancies; electrolyte composition; product distribution

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1 Introduction

The accumulation of plastic waste has turned into a global ecological concern nowadays [1, 2]. In this context, polylactic acid (PLA) is often considered a substitute for conventional petroleum-derived plastics, since it is made from bio-based materials and is biodegradable [3, 4]. PLA is used in various commercial products, including disposable tableware, cups, straws, and bags [5]. Nonetheless, biodegradability indicates whether a material can degrade, rather than the degradation rate. In fact, under ordinary environmental conditions, PLA breaks down very slowly, and its degradation rate varies substantially among different environments [4, 6, 7]. This can create a gap between public understanding and actual behavior: PLA, while seemingly environmentally friendly, may stay long after disposal [4, 6]. Therefore, it is important to efficiently convert PLA under mild conditions. Catalytic conversion is a potential approach to accelerate its degradation while also producing high-value molecules, rather than leaving PLA to degrade passively [8, 9, 10].

Several chemical ways have been studied for PLA conversion, including hydrolysis [4, 11] and alcoholysis [4, 12]. In these processes, catalysts help break the ester bonds, producing lactic acid or other chemicals [4, 12]. However, some reported methods require elevated temperatures, acidic or alkaline conditions, or additional reactants [4, 8]. By comparison, photocatalysis, in which light supplies the energy required for the reaction, can operate under milder conditions [8, 13-15]. The present work examines whether such mild photocatalytic conditions can be applied to PLA conversion.

Photocatalytic reforming uses solar energy and turns plastic waste into valuable chemicals [15, 16]. When illuminated, the semiconductor produces photogenerated electrons and holes. These electron-hole pairs interact with O_2 and H_2O to generate reactive oxygen species (ROS), which can attack PLA chains [8, 13, 16].

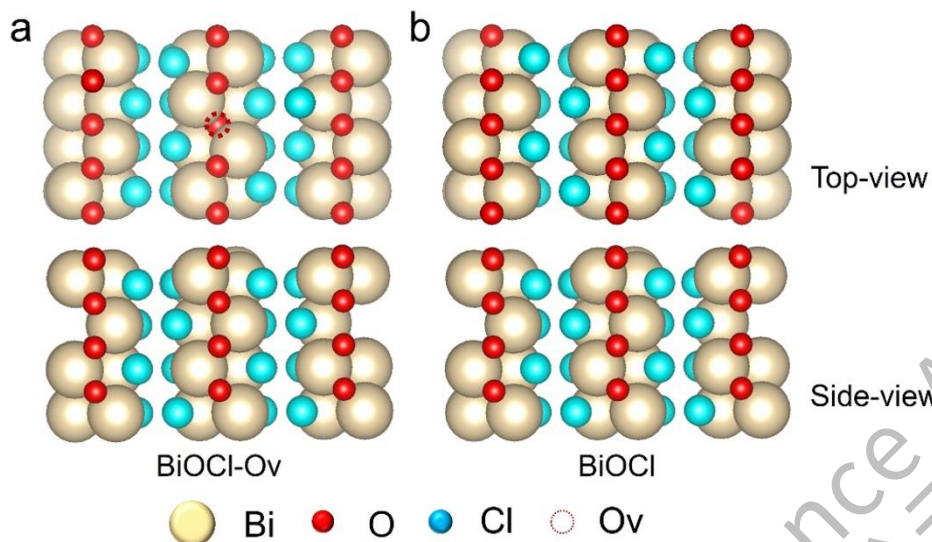


Figure 1. Model structures of (a) BiOCl-Ov and (b) BiOCl used for DFT calculations reported by Wang et al. [17].

In a recent study on photocatalysis, Wang et al. [17] reported the conversion of low-density polyethylene (LDPE) in aqueous NaCl using oxygen-vacancy-rich bismuth oxychloride (BiOCl-Ov) under ambient conditions. In this system, photogenerated holes activate interlayer lattice chloride in BiOCl-Ov to produce chlorine radicals. Meanwhile, the chloride ions in the electrolyte replenish the lattice chloride consumed during irradiation. The chlorine radicals then attack LDPE, breaking its C–H and C–C bonds and generating liquid products such as formic and acetic acids, together with gaseous CO₂. Figure 1 shows the structural difference between BiOCl-Ov and BiOCl. The missing oxygen site in the BiOCl-Ov structural model symbolizes the oxygen vacancy reported by Wang et al. [17].

However, PLA differs from LDPE because it contains ester bonds and may follow a different reaction pathway [8, 17]. The strong performance of BiOCl-Ov toward LDPE therefore does not necessarily mean that it will perform well with PLA. Whether oxygen vacancies and a chloride-containing environment are also beneficial for PLA needs further examination.

To explore this question, this study investigated photocatalytic conversion of PLA. Based on the proposed mechanism, BiOCl-Ov was initially expected to promote the

upgrading of PLA to high-valued products. Three photocatalysts, Bi_2O_3 , BiOCl , and BiOCl-Ov , were compared to examine differences in product formation. Air and Ar atmospheres were compared in order to explore the role of oxygen, while NaCl and Na_2SO_4 were used to check the impact of electrolyte composition during the process of photocatalytic product formation. Product formation after 3 and 12 h of irradiation was also compared to examine changes over time.

2 Experimental Methods

2.1 Materials and Catalyst Preparation

PLA powder and the Bi_2O_3 used as a comparison catalyst were from the laboratory. BiOCl and BiOCl-Ov were prepared following the procedure from Wang et al. [17]. To prepare BiOCl-Ov , 1.45 g of $\text{Bi}(\text{NO}_3)_3 \cdot 5\text{H}_2\text{O}$ and 0.22 g of KCl were mixed with 16 mL of ethylene glycol and stirred for 30 min at room temperature. Subsequently, the mixture was placed in a Teflon-lined 50 mL autoclave. The autoclave was maintained at 160 °C for 12 h and then cooled naturally. The resulting product was separated by centrifugation, repeatedly washed with ethanol and deionized water, and dried for 24 h at 80 °C. BiOCl was synthesized using the same procedure, except that deionized water was used instead of ethylene glycol.

2.2 Catalyst Characterization

X-ray diffraction (XRD) patterns of Bi_2O_3 , BiOCl , and BiOCl-Ov were examined to determine their crystal structures. Scanning electron microscopy (SEM) was employed for morphological comparison between BiOCl and BiOCl-Ov . The chemical environments of Bi, O, and Cl were examined through X-ray photoelectron spectroscopy (XPS). Optical absorption was measured by UV-visible spectroscopy, and the band gaps were derived from Kubelka-Munk plots.

2.3 Photocatalytic Experiments

Figure 2 shows the photocatalytic reaction setup [17]. This setup exposes the

reaction mixture to light and separates the gaseous and liquid products for analysis.

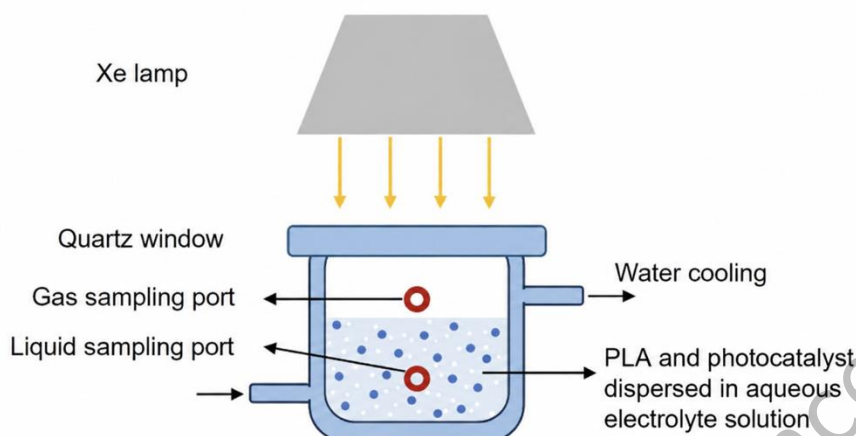


Figure 2. Schematic diagram of the photocatalytic reaction device reported by Wang et al. [17].

In each experiment, 20 mg of catalyst and 100 mg of PLA powder were added to 20 mL of a 0.5 M aqueous electrolyte medium. A xenon lamp rated at 300 W was used to provide illumination. Firstly, Bi_2O_3 , BiOCl , and BiOCl-Ov were tested in NaCl solution under air and Ar atmospheres for 3 h. Secondly, for BiOCl-Ov , additional experiments that replaced NaCl with Na_2SO_4 were conducted under both atmospheres—this compared the effect of electrolyte composition. Thirdly, a 12 h experiment with BiOCl-Ov in NaCl solution under air was also conducted to examine changes over a longer reaction time.

2.4 Product Analysis and Yield Calculation

Gas-phase products were quantified by gas chromatography (GC). Liquid samples were sent to an external testing service for nuclear magnetic resonance (NMR) analysis. Liquid product amounts were calculated from the recorded NMR peak areas [8]. The amount of CO_2 was calculated from its measured gas concentration, volume, pressure, and temperature for each experiment.

The measured amount of each product was normalized to the catalyst mass, and the yield was reported in $\mu\text{mol g}^{-1}$.

3 Results and Discussion

3.1 Catalyst Characterization

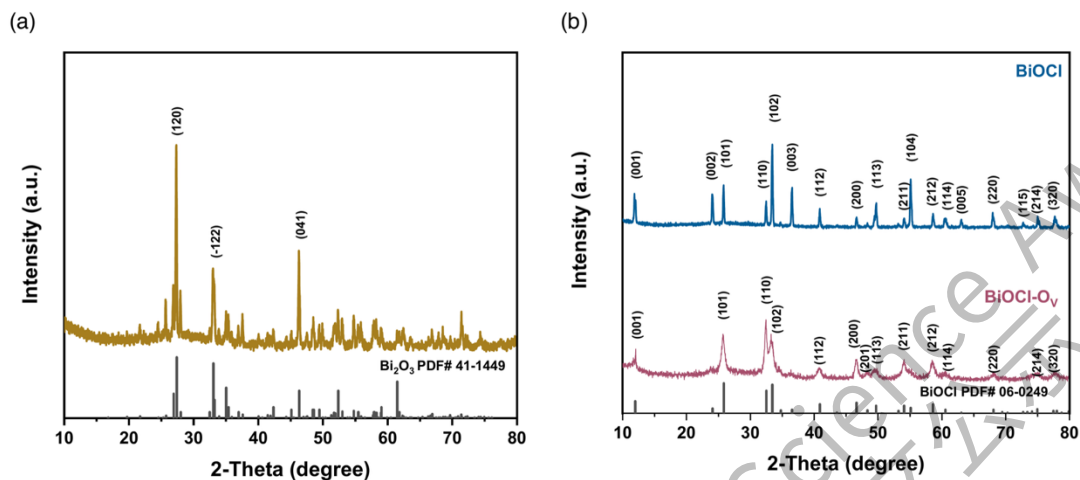


Figure 3. (a) XRD pattern of Bi_2O_3 . (b) XRD patterns of BiOCl and BiOCl-Ov .

The XRD patterns for the catalysts are presented in Figure 3. The peaks of Bi_2O_3 correspond to the standard pattern PDF#41-1449 shown in Figure 3a. As depicted in Figure 3b, both BiOCl and BiOCl-Ov show the standard tetragonal crystalline structure of BiOCl (PDF#06-0249) [17]. In addition, the peaks of BiOCl-Ov are broader than those of BiOCl , a difference that Wang et al. attributed to the smaller crystal size and structural distortion of BiOCl-Ov [17]. Thus, it can be concluded that the main structure of BiOCl remains the same even after the vacancy-forming synthesis. However, XRD is not sufficient for identifying oxygen vacancies.

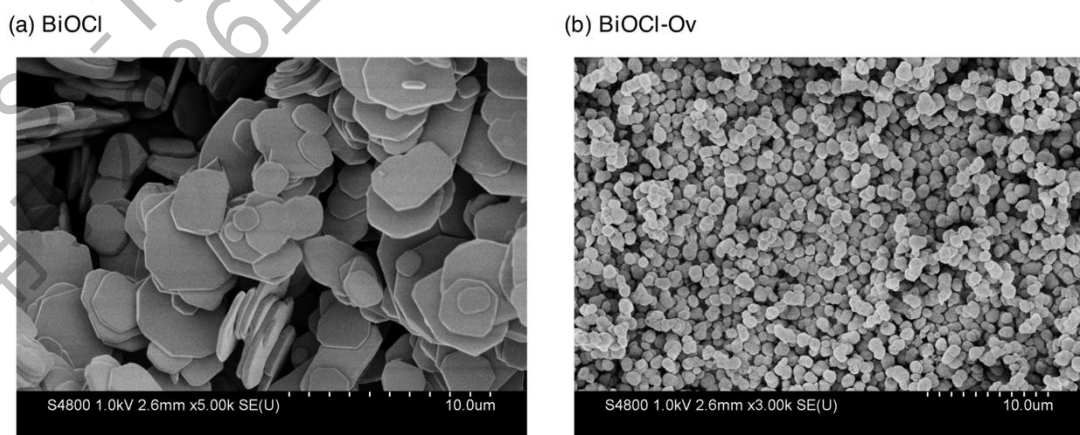


Figure 4. SEM images of (a) BiOCl and (b) BiOCl-Ov .

Figure 4 presents SEM micrographs of BiOCl and BiOCl-Ov. BiOCl appears mainly composed of smooth microsheets approximately 5–10 μm in size. In contrast, BiOCl-Ov consists of smaller, rounder particles that form microspheres around 0.5–2 μm in diameter [17]. This difference suggests that the use of ethylene glycol during preparation affected the particle formation.

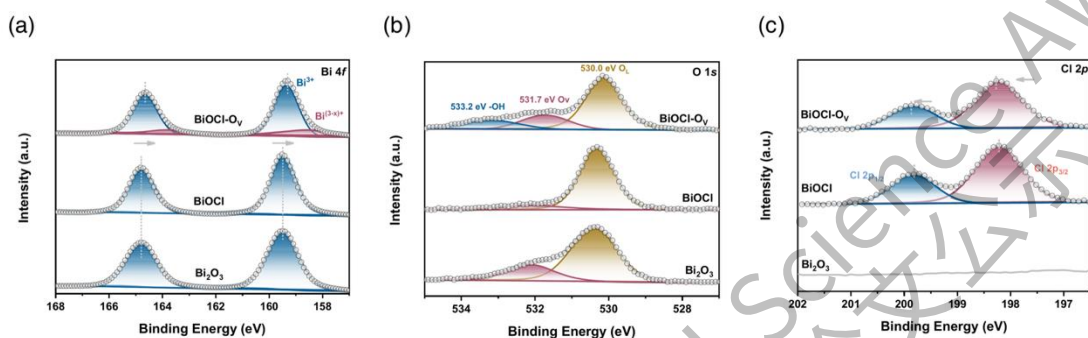


Figure 5. High-resolution XPS spectra of Bi₂O₃, BiOCl, and BiOCl-Ov in the (a) Bi 4f, (b) O 1s, and (c) Cl 2p regions.

The XPS results shown in Figure 5 were used to examine the chemical environments of Bi, O, and Cl. The main peaks in the Bi 4f spectra of Bi₂O₃ and BiOCl are attributed to Bi³⁺ species [17]. In the BiOCl-Ov sample, the peaks shift towards lower binding energies. Additionally, a signal attributable to partially reduced Bi species was observed [17]. For BiOCl-Ov, the O 1s signals at approximately 530.0, 531.7, and 533.2 eV were assigned to lattice oxygen, oxygen-vacancy-related species, and surface hydroxyl groups, respectively [17]. The oxygen-vacancy-related signal does not appear in either BiOCl or Bi₂O₃. Meanwhile, the oxygen-vacancy-related component does not appear in either BiOCl or Bi₂O₃. Also, a small shift can be seen in the Cl 2p spectrum of BiOCl-Ov relative to BiOCl. These findings support the presence of oxygen vacancy sites and the change in the electronic state of BiOCl-Ov.

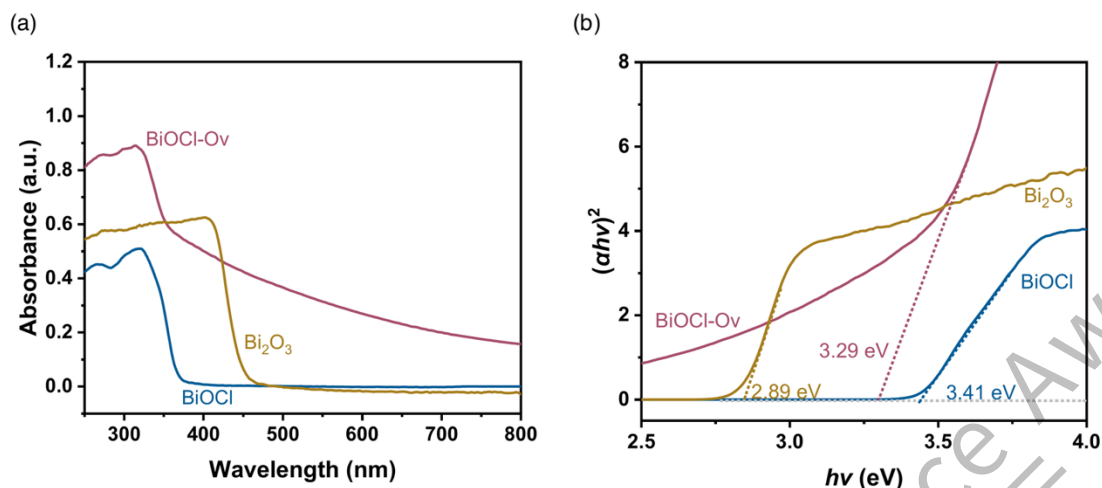


Figure 6. (a) UV-visible absorption spectra of Bi₂O₃, BiOCl, and BiOCl-Ov. (b) Kubelka–Munk plots used to estimate their band gaps.

The optical characteristics of these catalysts are displayed in Figure 6. The optical absorption edge of BiOCl-Ov shifts toward longer wavelengths compared with that of BiOCl, as displayed in Figure 6a. Based on Figure 6b, which displays the Kubelka–Munk plots, the band gaps of Bi₂O₃, BiOCl, and BiOCl-Ov are around 2.89 eV, 3.41 eV, and 3.29 eV, respectively. The band gap for BiOCl-Ov is lower than that of BiOCl [17]. This indicates that oxygen vacancies have altered the optical behavior of BiOCl.

3.2 Effects of Catalyst and Atmosphere

Figure 7a shows the product distributions of the three catalysts in NaCl solution under air after 3 h. For BiOCl-Ov, lactic acid was the dominant liquid product (2670.8 μmol g⁻¹), whereas the corresponding yield with BiOCl was 911.4 μmol g⁻¹. In contrast, the acetic acid yield was 1046.6 μmol g⁻¹ with BiOCl and 220.0 μmol g⁻¹ with BiOCl-Ov. The yields of CO₂, an overoxidation product, were 1055.7 μmol g⁻¹ for Bi₂O₃, 594.9 μmol g⁻¹ for BiOCl-Ov, and 1538.6 μmol g⁻¹ for BiOCl. Among the three catalysts, BiOCl-Ov showed the lowest CO₂ yield.

The higher lactic acid yield and lower acetic acid and CO₂ yields suggest that BiOCl-Ov favored lactic acid accumulation under these conditions. We next considered whether this difference in product distribution remained under Ar.

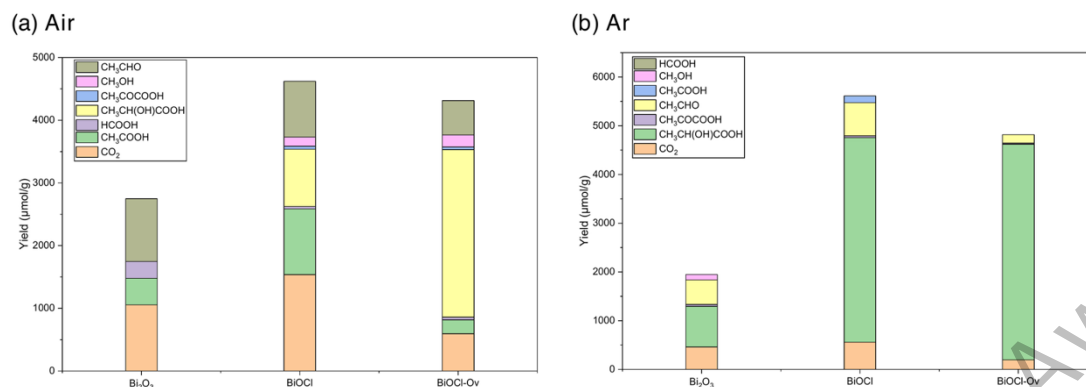


Figure 7. Yield of products from PLA conversion using Bi_2O_3 , BiOCl , and BiOCl-Ov in 0.5 M NaCl solution after 3 h under (a) air and (b) Ar.

Comparing Figures 7a and 7b shows the change in the product distribution as the atmosphere was varied from air to Ar. When using BiOCl-Ov , the lactic acid yield was higher under Ar, reaching $4426.3 \mu\text{mol g}^{-1}$ —it was only $2670.8 \mu\text{mol g}^{-1}$ under air. BiOCl showed a similar trend, with a lactic acid yield of $4201.1 \mu\text{mol g}^{-1}$ under Ar, compared with $911.4 \mu\text{mol g}^{-1}$ under air. Although BiOCl-Ov still gave the higher lactic acid yield, the difference in lactic acid yield between the two catalysts was much smaller under Ar.

The narrowing of this difference becomes more apparent when each catalyst is examined separately. For BiOCl under Ar, the lactic acid yield was approximately 4.61 times its value under air, while the corresponding ratio for BiOCl-Ov was 1.66. Both catalysts gave higher lactic acid yields under Ar than under air, but the increase was larger for BiOCl . Still, the close values under Ar do not mean that the two catalysts performed equally well.

Meanwhile, all three catalysts showed lower CO_2 yields under Ar. For BiOCl-Ov , the yield was $194.0 \mu\text{mol g}^{-1}$ under Ar and $594.9 \mu\text{mol g}^{-1}$ under air. BiOCl and Bi_2O_3 gave CO_2 yields of 555.7 and $458.0 \mu\text{mol g}^{-1}$ under Ar, respectively. These observations show that air did not improve the formation of every product. Under the tested conditions, Ar was associated with higher lactic acid yields for BiOCl and BiOCl-Ov ; air was associated with higher CO_2 yields. Therefore, the gas and liquid results need to be considered together when comparing the two atmospheres. However, these

measurements do not identify which reaction steps account for the differences between air and Ar.

3.3 Effect of Electrolyte Composition

Figure 8 shows the product yields from BiOCl-Ov in NaCl and Na₂SO₄ solutions after 3 h under air and Ar. Under Ar, as shown in Figure 8b, the lactic acid yield was 4426.3 $\mu\text{mol g}^{-1}$ in NaCl solution, compared with 457.0 $\mu\text{mol g}^{-1}$ in Na₂SO₄ solution. The yield in NaCl was therefore approximately 9.69 times that in Na₂SO₄. However, the CO₂ yield showed the opposite trend: 194.0 $\mu\text{mol g}^{-1}$ in NaCl and 559.7 $\mu\text{mol g}^{-1}$ in Na₂SO₄.

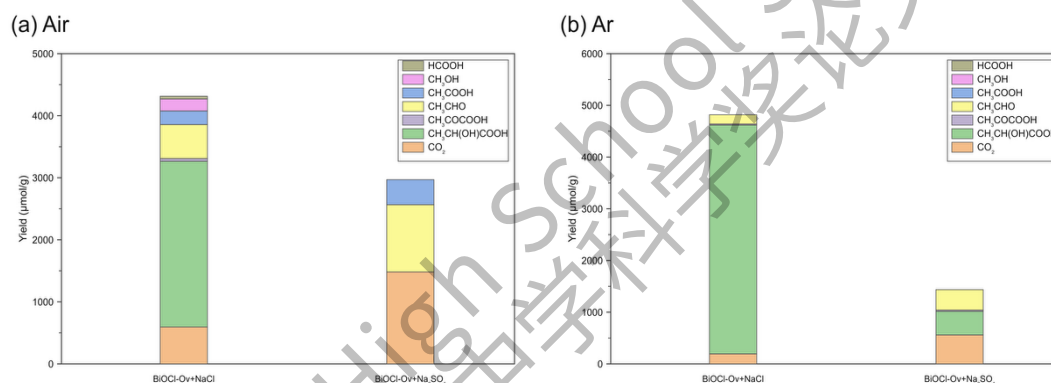


Figure 8. Yield of products from PLA conversion using BiOCl-Ov in 0.5 M NaCl and Na₂SO₄ solutions after 3 h under (a) air and (b) Ar.

Under air, as shown in Figure 8a, the lactic acid yield is 2670.8 $\mu\text{mol g}^{-1}$ in NaCl solution, but no lactic acid was detected in the Na₂SO₄ solution. On the other hand, the amount of CO₂ produced is 1482.9 $\mu\text{mol g}^{-1}$ in Na₂SO₄ solution and 594.9 $\mu\text{mol g}^{-1}$ in NaCl solution. The acetaldehyde yield was also higher in Na₂SO₄, at 1083.1 $\mu\text{mol g}^{-1}$, compared with 547.5 $\mu\text{mol g}^{-1}$ in NaCl. NaCl was replaced with Na₂SO₄ to examine the effect of chloride ions supplied by the electrolyte solution. According to the theory reported by Wang et al., the availability of chloride ions within the reaction medium helps restore lattice chloride ions that are lost due to irradiation [17]. The observed variations in product yield in the case of PLA indicate that the electrolyte also

influenced this system, but they do not establish whether the same replenishment process occurred.

3.4 Effect of Irradiation Time

Figure 9 compares the product yields obtained using BiOCl-Ov in NaCl solution under air after 3 and 12 h to examine the catalyst system during prolonged irradiation. The 12 h experiment was performed under continuous irradiation without intermediate sampling. The lactic acid yield decreased from 2670.8 $\mu\text{mol g}^{-1}$ at 3 h to 2110.9 $\mu\text{mol g}^{-1}$ at 12 h. In contrast, the acetic acid yield increased from 220.0 to 1730.5 $\mu\text{mol g}^{-1}$ over the same period. After 12 h, the yields of acetaldehyde and CO_2 reached 1325.7 and 1457.6 $\mu\text{mol g}^{-1}$, respectively, and both values were higher than those measured at 3 h.

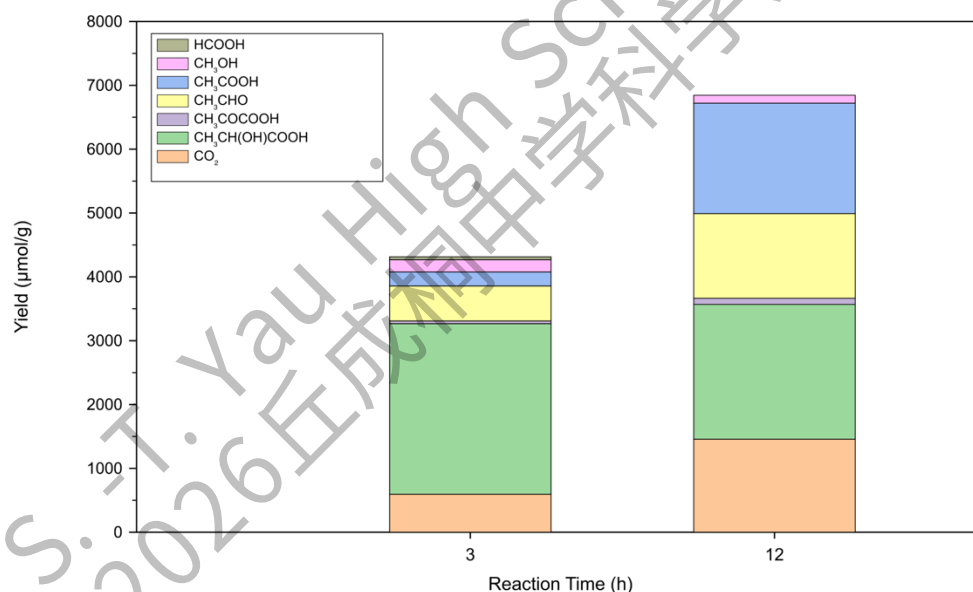


Figure 9. Yield of products from PLA conversion using BiOCl-Ov in 0.5 M NaCl solution under air after 3 and 12 h.

As shown in Figure 9, the lactic acid and acetic acid yields changed in opposite directions. The yield of lactic acid at 12 h was about 21% lower than that at 3 h, while the acetic acid yield at 12 h was about 7.87 times its value at 3 h. At 12 h, the lactic acid

yield was still higher than the acetic acid yield, but the difference between them was much smaller.

A longer irradiation period failed to increase all the measured yields in the tested system. The lower lactic acid yield, together with higher yields of acetic acid, acetaldehyde, and CO₂, may reflect further reactions during irradiation. The higher yields of several products after 12 h provide an initial indication that the BiOCl-Ov system remained active during prolonged irradiation. However, we still cannot conclude that lactic acid was converted into those products.

3.5 Overall Discussion

The PLA experiments show that the performance of BiOCl-Ov needs to be considered in terms of both reaction conditions and product formation. Under air, BiOCl-Ov gave a higher lactic acid yield than BiOCl, together with lower acetic acid and CO₂ yields. Moreover, the difference in lactic acid yield between BiOCl and BiOCl-Ov was smaller when the reaction proceeded under Ar conditions.

The electrolyte experiment was aimed at investigating the effect of Cl⁻ ions provided by the solution. In the case of BiOCl-Ov under an Ar atmosphere, the replacement of NaCl with Na₂SO₄ resulted in less lactic acid and more CO₂ production. However, this information does not show the exact function of Cl⁻ in PLA product formation.

4 Conclusion

This work examined product formation from PLA under photocatalytic conditions and the influences of the catalyst, atmosphere, electrolyte, and irradiation time. In NaCl solution under air for 3 h, BiOCl-Ov produced more lactic acid but less acetic acid and CO₂ than BiOCl, showing that it favored lactic acid accumulation under these conditions.

Gas and liquid products also behaved differently with respect to changing conditions during the reaction. A higher CO₂ yield was not always accompanied by a

higher lactic acid yield. Product distribution should therefore be considered explicitly, rather than evaluating the system on the basis of a single product. Furthermore, the comparisons among photocatalysts need to be interpreted together with the atmosphere and electrolyte conditions.

In conclusion, the current studies reveal that the catalyst, atmosphere, electrolyte, and irradiation period affect the products formed from PLA. The findings provide conditions that promote lactic acid formation and provide a basis for future research on the role of chlorides and the catalyst under prolonged irradiation.

5 References

- [1] Geyer, R.; Jambeck, J. R.; Law, K. L. Production, Use, and Fate of All Plastics Ever Made. *Sci. Adv.* 2017, 3, e1700782.
- [2] MacLeod, M.; Arp, H. P. H.; Tekman, M. B.; Jahnke, A. The Global Threat from Plastic Pollution. *Science* 2021, 373, 61–65.
- [3] Nampoothiri, K. M.; Nair, N. R.; John, R. P. An Overview of the Recent Developments in Polylactide (PLA) Research. *Bioresour. Technol.* 2010, 101, 8493–8501.
- [4] McKeown, P.; Jones, M. D. The Chemical Recycling of PLA: A Review. *Sustainable Chemistry* 2020, 1, 1–22.
- [5] Ya, Z.; Li, M.; Xu, D.; Wang, H.; Zhang, S. Asymmetric Atomic Pt–B Dual-Site Catalyst for Efficient Photoreforming of Waste Polylactic Acid Plastics in Seawater. *ACS Nano* 2025, 19, 16011–16023.
- [6] Chamas, A.; Moon, H.; Zheng, J.; Qiu, Y.; Tabassum, T.; Jang, J. H.; Abu-Omar, M.; Scott, S. L.; Suh, S. Degradation Rates of Plastics in the Environment. *ACS Sustainable Chem. Eng.* 2020, 8, 3494–3511.
- [7] Rudnik, E.; Briassoulis, D. Degradation Behaviour of Poly(lactic acid) Films and Fibres in Soil under Mediterranean Field Conditions and Laboratory Simulations Testing. *Ind. Crops Prod.* 2011, 33, 648–658.
- [8] Miao, Y.; Zhao, Y.; Gao, J.; Wang, J.; Zhang, T. Direct Photoreforming of Real-World Polylactic Acid Plastics into Highly Selective Value-Added Pyruvic Acid under Visible Light. *J. Am. Chem. Soc.* 2024, 146, 4842–4850.
- [9] Hu, Q.; Zhang, Z.; He, D.; Wu, J.; Ding, J.; Chen, Q.; Jiao, X.; Xie, Y. Progress and Perspective for “Green” Strategies of Catalytic Plastics Conversion into Fuels by Regulating Half-Reactions. *J. Am. Chem. Soc.* 2024, 146, 16950–16962.
- [10] Rahimi, A.; García, J. M. Chemical Recycling of Waste Plastics for New Materials Production. *Nat. Rev. Chem.* 2017, 1, 0046.
- [11] Uekert, T.; Kuehnle, M. F.; Wakerley, D. W.; Reisner, E. Plastic Waste as a Feedstock for Solar-Driven H₂ Generation. *Energy Environ. Sci.* 2018, 11, 2853–2857.

- [12] Petrus, R.; Bykowski, D.; Sobota, P. Solvothermal Alcoholysis Routes for Recycling Polylactide Waste as Lactic Acid Esters. *ACS Catal.* 2016, 6, 5222–5235.
- [13] Uekert, T.; Kasap, H.; Reisner, E. Photoreforming of Nonrecyclable Plastic Waste over a Carbon Nitride/Nickel Phosphide Catalyst. *J. Am. Chem. Soc.* 2019, 141, 15201–15210.
- [14] Liu, C.-X.; Liu, K.; Xu, Y.; Wang, Z.; Weng, Y.; Liu, F.; Chen, Y. Photocatalytic Upgrading of Polylactic Acid Waste into Alanine under Mild Conditions. *Angew. Chem. Int. Ed.* 2024, 63, e202401255.
- [15] Uekert, T.; Pichler, C. M.; Schubert, T.; Reisner, E. Solar-Driven Reforming of Solid Waste for a Sustainable Future. *Nat. Sustain.* 2021, 4, 383–391.
- [16] Zhou, G.; Xu, H.; Song, H.; Yi, J.; Wang, X.; Chen, Z.; Zhu, X. Photocatalysis toward Microplastics Conversion: A Critical Review. *ACS Catal.* 2024, 14, 8694–8719.
- [17] Wang, H.; Wen, Q.; Yan, X.; Ma, J.; Wang, C.; Han, Q.; Zhang, L.; Zheng, G. Chlorine Ion-Enhanced Efficient Photocatalysis of Polyethylene Plastics. *ACS Nano* 2026, 20, 15363–15371.

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在 2026 年 2 月,我有幸认识了郑耿锋教授并在复旦大学江湾校区接受指导、开展实验研究。通过参与本课题,我接触并学习了许多高中课程以外的化学知识和实验方法,对光催化、材料表征以及实验数据分析有了更加深入的认识。

在为期半年多的研究过程中,我首先阅读了关于聚乳酸降解、塑料光催化转化、氯化铋及氧空位等方面的中英文文献。这使我逐步了解了相关研究背景,并在老师和师姐的指导下逐步确定实验方案。随后,我参与了 BiOCl 和富氧空位 BiOCl 催化剂的制备,使用制备好的材料完成了不同催化剂、反应气氛、电解质和光照时间条件下的光催化实验。同时,我还实际操作并学习了 X 射线衍射仪、紫外-可见分光光度计和气相色谱仪的基本使用方法;这些数据帮助了我整理实验结果、计算各类产物的产率、制作图表并比较不同实验条件下的产物分布。液体产物的核磁共振样品由我整理并送交外部检测机构测试。通过这样的流程,我完成了实验结果的分析、英文论文的主体撰写以及后续修改和排版工作。

本课题的研究方向和具体选题由郑耿锋老师提出并确定。在整个研究过程中,老师帮助设计了实验方案,并为研究提供实验室、实验材料和仪器条件。他向我讲解相关实验原理和仪器使用方法,让我逐渐适应了实验室的研究流程。在数据分析和论文写作过程中,郑老师也不断帮助我理解了实验现象、判断不同条件对产物形成的影响,并面对面讨论了论文内容。研究过程中未向郑老师支付任何指导报酬。

同时,我也要特别感谢王慧宁师姐对我的帮助。在研究之初,她指导我学习催化剂制备方法和光催化实验的基本操作,帮助我熟悉实验流程,在她的指导下,我还逐步掌握了气相色谱仪的基本使用方法。本研究中的 SEM 和 XPS 测试由王师姐完成。令我印象最深刻的是,当实验数据较多、不同产物和反应条件不易整理时,她指导我建立表格、分类记录数据,这使我能够更清楚地比较和分析实验结果。

研究过程中,我也遇到了一些困难,例如英文文献中的专业词汇较多,部分内容难以理解。在独立阅读的基础上,我使用翻译及人工智能工具辅助理解专业术语和复杂句子,再结合老师的讲解和不同文献之间的相互印证,逐步加深理解。

最后，我衷心感谢郑耿锋老师在研究方向、实验设计、数据分析和论文写作方面给予的耐心指导，感谢王慧宁师姐在实验操作、仪器测试和数据整理方面给予的细致帮助。这段研究经历不仅让我学习了具体的实验技能，也使我认识到科学研究需要严谨记录、反复比较和谨慎得出结论。

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