《光学学报》“英文长摘要”格式要求

1、篇幅：英文长摘要篇幅要求在800~1200字（单词数）。

2、结构：

（1）题目、作者和单位（与中文信息对应的英文信息）

（2）英文长摘要正文：

1）研究意义**(Significance)**（主要突出本领域研究的重要性）；

2）研究进展**(Progress)**（本领域的重要研究进展）：请标示出所对应的正文中的图表，以括号标注，如 (Fig.5) 等；

3）结论与展望**(Conclusions and Prospects)**

（3）关键词**(Key words)**。

3、不要加参考文献。如果有引用其他文章，建议作者转述。

4、请删除原英文摘要。

5、“英文长摘要”题目中的单词首字母请大写（除介词外）。

6、“英文长摘要”请放在文末，另起一页。

附综述参考示例：

Laser Fabricated Electrodes with Micro-Nano Structures for Electrocatalytic Water Splitting

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Abstract

Significance It is well known that energy, material and information have been regarded as the three cornerstones of human civilization and social development. The exploitation and utilization of energy by human beings has been running through the process of human evolution without interruption. Fossil fuels, including coal, oil and natural gas, have promoted tremendous social changes and brought inestimable value to human beings. Traditional fossil fuels are non-renewable energy sources, of which the reserves in the earth's crust are limited. Excessive exploitation will inevitably lead to the depletion of fossil fuels. Due to the increasing environmental pollutions, human beings began to realize environmental hazards caused by the excessive use of fossil fuels, such as global warming, acid rain and particulate matters. With regard to the severe energy and environmental crisis, it is imperative to develop green and clean energy technologies to reduce the use of increasingly exhausted fossil fuels and achieve environmental-friendly and sustainable social developments.

Hydrogen, as a renewable energy carrier, has attracted numerous attention due to the following four reasons. Firstly, hydrogen is a clean and low-carbon energy carrier and its reaction product is merely water without carbon dioxide emission. Secondly, hydrogen has a high calorific value, which is about three times larger than fossil fuels. Thirdly, hydrogen is widely used in electricity, construction, transportation and industrial fields. It can be used as not only raw materials for steel, metallurgy and chemical industries, but also the fuel for fuel cells. Fourthly, hydrogen is earth-abundant, which can originate from fossil fuel reforming, water splitting and by-products of chlor-alkali industry. Many governments around the world are committed to developing hydrogen energy and arranging relevant industrial chains. The International Renewable Energy Agency pointed out that hydrogen can build the interconnection among electricity, construction, industry and transportation to achieve the deep decarbonization.

Developing various technologies for hydrogen production is important to develop hydrogen energy. Nowadays, there are three main pathways for hydrogen production, namely, methane-steam reforming, coal gasification and electrocatalytic water splitting. Though the first two pathways account for about 95% of the whole hydrogen, they still rely on fossil fuels and emit large amounts of carbon dioxide, which violates the goal of developing hydrogen energy. In contrast, electrocatalytic water splitting does not lead to carbon emissions, and is an absolutely green and sustainable hydrogen production technology. However, electrocatalytic water splitting has the shortcoming

of excessive energy consumption and high cost, which restricts its large-scale application. Electrocatalytic water splitting contains cathodic hydrogen evolution reaction (HER) and anodic oxygen evolution reaction (OER), both which need efficient electrocatalysts to overcome the high reaction barrier. Therefore, how to improve the catalytic performance of the electrocatalysts and reduce the electrolytic overpotential is the key to realize the large-scale application of electrocatalytic water splitting.

In the past few years, various methods have been developed to prepare electrocatalysts for electrocatalytic water splitting, mainly including hydrothermal/solvothermal method, sol-gel method, electrochemical deposition, chemical bath deposition, chemical vapor deposition and physical vapor deposition. Especially, laser has become an effective tool to prepare catalysts for electrocatalytic water splitting with advantages of being efficient, flexible, non-contact and highly controllable. Many corresponding advances have been achieved, but they still face a series of challenges in terms of industrial feasibility and performance improvement. Hence, it is important and necessary to summarize the existing research to guide the future development of this field more rationally.

Progress The preparation method of electrocatalysts for electrocatalytic water splitting based on laser and their catalytic performances are summarized (Table 1). First, the implementation process of electrocatalytic water splitting, evaluation parameters, classification and preparation methods of electrocatalysts are introduced. The evaluation parameters include overpotential, Tafel slope, stability, Faradic efficiency, and turnover frequency. Then, the catalytic performances of electrocatalysts prepared by laser are comprehensively summarized according to previously reported studies. Subsequently, powder catalysts by laser in liquid and self-supported catalytic electrodes with micro-nano structures by laser are elaborated. Considering the interaction mechanism, the preparation process of powder catalysts by laser can be divided into laser irradiation in liquid and laser ablation in liquid (Fig.3). Haimei Zheng's research group from University of California, Berkeley, has taken relatively pioneering studies on laser irradiation in liquid. Xiwen Du's research group from Tianjin University has engaged in plenty of systematic studies on laser ablation in liquid. Based on the preparation method, the preparation process of self-supported catalytic electrodes with micro-nano structures by laser can be divided into laser direct preparation and laser hybrid with other chemical synthesis methods (Fig.5). The studies about self-supported catalytic electrodes by laser are still limited and incomprehensive. In the end, the problems faced and the ongoing research trends in this field are discussed, including the type of laser, the characterization and theoretical calculation of catalysts, the design of bifunctional catalysts, and the performance evaluation in industrial conditions.

Conclusions and Prospects Laser is gradually becoming a popular tool to prepare various functional materials. In summary, the preparation of micro-nano catalysts for electrocatalytic water splitting by laser still needs in-depth and detailed explorations to promote the development of this hydrogen production technology in academic and engineering aspects.

Key words laser; micro-nano structures; electrocatalytic water splitting; oxygen evolution reaction; hydrogen evolution reaction