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為潔淨能源注入新動能 彭維鋒論文躍登美國頂尖JACS期刊

學習新視界

【記者陳宇暄淡水校園報導】物理系特聘講座教授彭維鋒與臺灣大學和國家同步輻射研究中心團隊，共同發表「In Situ Identification of Spin Magnetic Effect on Oxygen Evolution Reaction Unveiled by X-ray Emission Spectroscopy」，4月刊登於國際頂尖期刊《Journal of the American Chemical Society, JACS》，影響因子達14.4，為美國化學學會所發行的Q1期刊，具有150年歷史，在物理與化學相關領域，成為國際公認具代表性科研期刊之一。

彭維鋒指出，此項研究首次利用同步輻射X射線發射（XES）與吸收光譜（XAS），在施加磁場條件下，量測具備磁性的尖晶石材料「鈷鐵氧化物（CoFe□O□）」催化劑，在氧氣演化反應（Oxygen Evolution Reaction, OER）條件中，觀察鐵與鈷原子的電子自旋態演化。研究結果說明磁性與催化活性間的密切關聯，已成為目前綠能材料最新研究成果，未來將可應用淨零轉型的關鍵氫能計畫中選項。

這篇重要論文由彭維鋒與臺大材料系教授陳俊維團隊，及國家同步輻射研究中心科學團隊等，共同合作發表成果，彭維鋒與陳俊維共同擔任論文通訊作者，第3作者為本校應用科學博三林暐軒、第4作者應科博五陳冠宏，他們同為物理系「吸收光譜實驗室」成員。其他作者尚有國家同步輻射中心3位同仁包志文、詹智全和邵禹成，及國立高雄大學應用物理系教授兼系主任邱昭文，他們都是物理系校友，彭維鋒指導的博士生。

彭維鋒表示，透過國家同步輻射研究中心TPS 44光束線，與臺灣自主建置BL12XU光束線于日本Spring 8，研究團隊得以突破過往技術瓶頸，從電子自旋角度重新理解磁場催化反應，這對於未來推動高效能水分解製氫，以及發展低碳能源材料，具有重要科學意義與應用潛力。「這項研究成果展現本校物理系在同步輻射技術，與能源材料研究領域之重要實力，也為潔淨能源技術突破注入新的動能。」

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Article

In Situ Identification of Spin Magnetic Effect on Oxygen Evolution Reaction Unveiled by X-ray Emission Spectroscopy

Chih-Ying Huang, Hsin-An Chen, Wei-Xuan Lin, Kuan-Hung Chen, Yu-Chang Lin, Tai-Sing Wu, Chia-Che Chang, Chih-Wen Pao, Wei-Tsung Chuang, Jyh-Chyuan Jan, Yu-Cheng Shao, Nozomu Hiraoka, Jau-Wern Chiou, Pai-Chia Kuo, Jessie Shiue, Deepak Vishnu S. K, Raman Sankar, Zih-Wei Cyue, Way-Faung Pong,* and Chun-Wei Chen*

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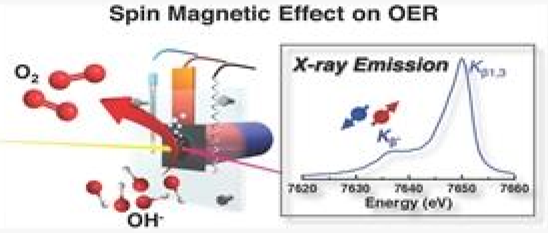

ABSTRACT: Manipulating the spin ordering of the oxygen evolution reaction (OER) catalysts through magnetization has recently emerged as a promising strategy to enhance performance. Despite numerous experiments elaborating on the spin magnetic effect for improved OER, the origin of this phenomenon remains largely unexplored, primarily due to the difficulty in directly distinguishing the spin states of electrocatalysts during chemical reactions at the atomic level. X-ray emission spectroscopy (XES), which provides information sensitive to the spin states of specific elements in a complex, may serve as a promising technique to differentiate the onset of OER catalytic activities from the influence of spin states. In this work, we employ the in situ XES technique, along with X-ray absorption spectroscopy (XAS), to investigate the interplay between atomic/electronic structures, spin states, and OER catalytic activities of the CoFe$_2$O$_4$ (CFO) catalyst under an external magnetic field. This enhancement is due to the spin magnetic effect that facilitates spin-selective electron transfer from adsorbed OH$^-$ reactants, which strongly depends on the spin configurations of the tetrahedral-(T_d) and octahedral-(O_h) sites of both Fe and Co ions. Our result contributes to a comprehensive understanding of magnetic field-assisted electrocatalysis at the atomic level and paves the way for designing highly efficient OER catalysts.

1. INTRODUCTION

Electrochemical water splitting, comprising hydrogen evolution reaction (HER) and oxygen evolution reaction (OER), is a highly promising technology for generating clean hydrogen essential for sustainable energy conversion.[1,2] The major challenge lies in finding efficient, cost-effective, and durable catalysts to enhance the cathodic HER and anodic OER at low overpotentials. In particular, the high activation barriers and sluggish kinetics of OER limit the overall efficiency of water electrolysis, so there is an urgent demand for low-cost, efficient, and stable catalysts for OER.[3,4] The general strategy to design electrocatalysts with improved performances is either increasing the number of active sites[5] or enhancing the intrinsic activity of individual active sites.[6] Because the ground state of dioxygen is a spin triplet with about 1 eV lower than the excited state of dioxygen and the reactants (H$_2$O and OH$^-$),[7] which are a spin singlet, manipulation of electronic spin has recently emerged as a promising strategy to boost the performance of OER catalysts.[8] Spin-polarized electrons on the catalyst surface play a crucial role in promoting the generation of parallel spin-aligned oxygens, thereby enhancing the performance of the OER. This enhancement is often observed when interatomic ferromagnetic (FM) interactions of the catalyst dominate, which facilitates the spin-selective electron transfer from singlet reactants to form triplet dioxygen. Consequently, this mechanism leads to improved catalytic activity, as explained by the theory of quantum spin-exchange interactions (QSEI).[9] Further magnetization by an external magnetic field may increase the spin polarization of FM catalysts, thus enhancing the OER performance.

Several research groups have experimentally demonstrated the spin magnetic effect on OER. They have shown that applying a direct magnetic field can enhance electrocatalytic water oxidation, with the enhancement positively correlated with magnetization.[10−13] For example, Galán-Mascarós et al. reported that the OER activity of group VIII metal oxides, such as NiZnFeO$_x$, is significantly enhanced when an external field is applied.[14] Xu et al. revealed that spin polarization induced by

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Spin Magnetic Effect on OER