【Department Spotlight】Distinguished Chair Professor Way-Faung Pong 's Paper Published in Leading U.S. Journal JACS, Advancing Clean Energy Research

Campus focus

Distinguished Chair Professor Way-Faung Pong from the Department of Physics, in collaboration with research teams from National Taiwan University (NTU) and the National Synchrotron Radiation Research Center (NSRRC), co-authored a paper titled “In Situ Identification of Spin Magnetic Effect on Oxygen Evolution Reaction Unveiled by X-ray Emission Spectroscopy”, which was published in April in the prestigious international journal, Journal of the American Chemical Society (JACS). The journal, published by the American Chemical Society, has an impact factor of 14.4 and a history spanning 150 years, making it one of the most authoritative Q1 journals in physics and chemistry.

Prof. Pong noted that this study is the first to utilize synchrotron-based X-ray Emission Spectroscopy (XES) and X-ray Absorption Spectroscopy (XAS) under applied magnetic field conditions to observe the spin state evolution of iron and cobalt atoms in the magnetic spinel catalyst CoFe□O□ during the Oxygen Evolution Reaction (OER). The results demonstrate a significant correlation between magnetic properties and catalytic activity, representing a green energy materials research breakthrough. This discovery opens promising applications in hydrogen energy, a key component in global net-zero transformation strategies.

The paper was co-authored by Professor Pong and Distinguished Professor Chun-Wei Chen from the Department of Materials Science and Engineering at NTU, along with scientists from the NSRRC. Professors Pong and Chen served as corresponding authors. The third and fourth authors are Tamkang University Ph.D. students Wei-Xuan Lin (3rd-year) and Kuan-Hung Chen (5th-year), both of the Physics Department’s Absorption Spectroscopy Laboratory. Other co-authors include three researchers from NSRRC, Dr. Chih-Wen Pao, Dr. Jyh-Chyuan Jan, and Dr. Yu-Cheng Shao, as well as

Professor Jau-Wern Chiou, Chair of the Department of Applied Physics at National University of Kaohsiung. All are Tamkang's Physics Department alumni and former doctoral students under Professor Pong's guidance. Pong emphasized that, with the support of Taiwan Photon Source (TPS) beamline 44 at NSRRC and the domestically developed BL12XU beamline at Japan's SPring-8 synchrotron facility, the team overcame prior technical limitations to reinterpret magnetic field-driven catalysis from an electron spin perspective. This breakthrough holds significant scientific value and application potential for developing high-efficiency water-splitting hydrogen production and low-carbon energy materials. "This research highlights the strong capabilities of Tamkang University's Department of Physics in synchrotron radiation techniques and energy materials science," Pong remarked. "It also injects new momentum into advancing clean energy technologies."


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Article

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

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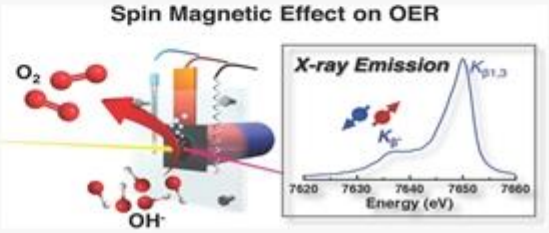
ABSTRACT: Manipulating the spin ordering of the oxygen evolution reaction (OER) catalysts through magnetization has recently emerged as a promising strategy to enhance performance. Despite numerous experiments elaborating on the spin magnetic effect for improved OER, the origin of this phenomenon remains 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 $CoFe_2O_4$ (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_2O 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