# Bio-inspired metal-N4 macrocyclic compounds for next-generation fuel-cell electrocatalysts

## Corrine- and corrole-based promising nonprecious metal electrocatalysts for the oxygen reduction reaction (ORR) in polymer electrolyte fuel cells (PEFCs)

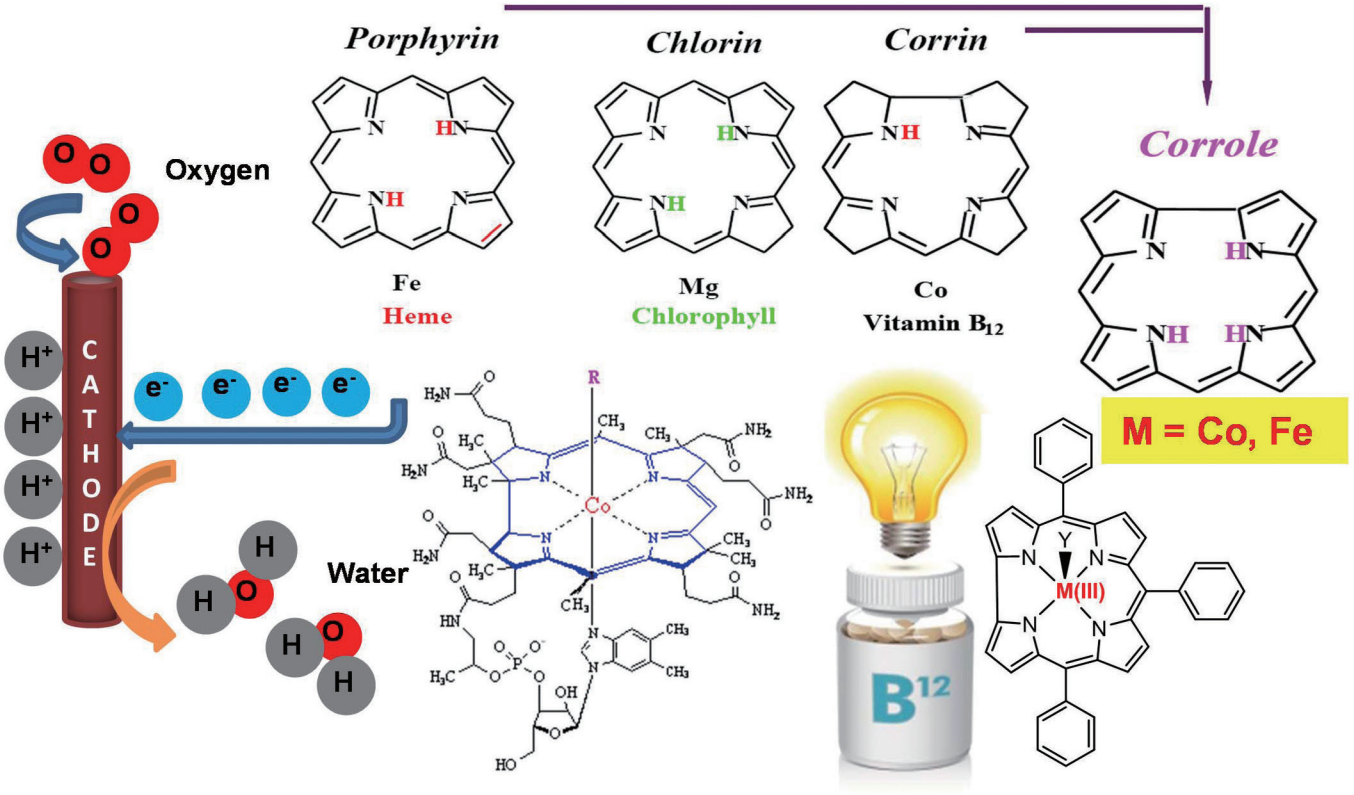
*For fuel-cell applications with reasonable cost as a widespread alternative energy conversion technology, scientists must learn from nature to replace the precious platinum electrocatalyst in the cathode. The research team led by Li-Chyong Chen, Kuei-Hsien Chen and Ken-Tsung Wong at the Center for Condensed Matter Sciences and Department of Chemistry, National Taiwan University, has developed a series of promising nonprecious metal-N4 electrocatalysts for the oxygen reduction reaction (ORR) in fuel-cell cathodes. Specifically, pyrolyzed vitamin B12 (Co-corrine), Co/Fe corrole and their bimetallic derivatives have been demonstrated to have promising ORR activity and stability. These research outcomes make nonprecious metal-N4 macrocyclic compound-based electrocatalysts viable candidates as Pt substitutes in polymer electrolyte fuel cells (PEFCs).*

A fuel cell is a device that converts chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent, potentially resulting inlow (or zero) carbon emissions and high efficiency. However, the limited natural abundance, high cost and carbon monoxide deactivation of Pt and other noble metals represent a major barrier in their application in hydrogen or methanol fuel cells. Therefore, the development of alternative electrocatalytic materials based on nonprecious metals is a key challenge in the recently growing demand for clean-energy fuel cell research. Natural bio-molecules serve as an inspiration for development of sustainable fuel producing systems. As a material scientist, Li-Chyong dreams to explore alternative catalysts, specifically, novel classes of macrocyclic compounds with biomimetic functionalities mimicking natural metabolism and respiration. The challenge she likes to tackle is whether nonprecious macrocyclic supramolecules can be effective energy boosters with enhanced oxygen reduction reaction (ORR) activity and overall energy conversion efficiency comparable to, or even outperforming, those of Pt.

Corrine and corrole have been shown to be versatile macrocyclic compounds that can coordinate with transition metals without significant distortion of the macrocycle planes that create these N4-ligands, for redox reactions in catalytic applications and hence for efficient ORR activity. Realization of the structural benefits of these macrocyclic compounds is important in advancing this field, not only for the scientific value of the fundamental understanding of catalysis in connection to nature but also for the technological potential of developing an environmentally friendly, affordable and efficient polymer electrolyte fuel cell (PEFC). Pyrolyzed vitamin B12 supported by carbon black (py-B12/C) uses one of the cheapest and most abundant materials on earth: carbon. When loaded with vitamin B12, while still not as efficient as Pt, py-B12/C performed well enough to show some promise. To further explore and hunt for more efficient nonprecious metal-N4 ORR electrocatalysts, the team has developed several metal corrole-based systems. Recently, a hybrid bimetallic-N4 electrocatalyst was derived from a pyrolyzed ferrocene-Co-corrole complex and successfully utilized for ORR.

**References**

1. Sun-Tang Chang, Chen-Hao Wang,* He-Yun Du, Hsin-Cheng Hsu, Chih-Ming Kang, Chia-Chun Chen, Jeffrey C. S. Wu, Shi-Chern Yen, Wen-Fei Huang, Li-Chyong Chen,* Ming-Chang Lin and Kuei-Hsien Chen*, (2012) Vitalizing fuel cells with vitamins: pyrolyzed vitamin B12 as a non-precious catalyst for enhanced oxygen reduction reaction of polymer electrolyte fuel cells. *Energy & Environmental Science* 5,




5305. DOI: 10.1039/c1ee01962g.

2. Hsin-Chih Huang, Indrajit Shown, Sun-Tang Chang, Hsin-Cheng Hsu, He-Yun Du, Ming-Cheng Kuo, Ken-Tsung Wong, Sea-Fu Wang, Chen-Hao Wang, Li-Chyong Chen, and Kuei-Hsien Chen, (2012). Pyrolyzed cobalt corrole as a potential non-precious catalyst for fuel cells. *Advanced Functional Materials*, 22, 3500–3508. DOI: 10.1002/adfm.201200264.

3. Hsin-Chih Huang, Chen-Hao Wang,* Indrajit Shown, Sun-Tang Chang, Hsin-Cheng Hsu, He-Yun Du, Li-Chyong Chen and Kuei-Hsien Chen*, (2013). High-performance pyrolyzed iron corrole as a potential non-precious metal catalyst for PEMFCs. *Journal of Materials Chemistry A*, 1, 14692–14699. DOI: 10.1039/c3ta13515b.

4. Satyanarayana Samireddi, Indrajit Shown, Tzu-Hsien Shen, Hsin-Chih Huang, Ken-Tsung Wong, Li-Chyong Chen* and Kuei-Hsien Chen*, (2017). Hybrid bimetallic-N4 electrocatalyst derived from a pyrolyzed ferrocene-Co-corrole complex for oxygen reduction reaction, *Journal of Materials Chemistry A*, 5, 9279–9286. DOI: 10.1039/c7ta00949f.

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