Generating Power from Vitamin B12

This report features the works of Kuei-Hsien Chen, Chen-Hao Wang, and their co-workers published in Energ. Environ. Sci. ***5****, 5305 (2012) and Int. J. Hydrogen Energ.* ***37****, 13755 (2012).*

Fuel cells, producing heat, water and nitrogen dioxide in small proportion, depending on the fuel source, provide green energy. The energy efficiency of fuel cells is generally between 40 and 60 %, or up to 85 % if waste heat is captured for use. Electrochemical devices of fuel cells generally have an oxygen reduction reaction (ORR) at the cathode and a hydrogen reduction reaction at the anode. The ORR plays a determining role for power generation because of its nature as a reaction much slower than the hydrogen reduction. Loading noble-metal catalysts (such as platinum) in large amounts onto the cathode can efficiently accelerate the ORR rate, but the great cost of the catalysts impedes the development of fuel cells. Prof. Kuei-Hsien Chen (Academia Sinica, Taiwan) and Prof. Chen-Hao Wang (National Taiwan University of Science and Technology, Taiwan) devoted their efforts to develop a cheap replacement of cathode materials by combining vitamin B12 and carbon black (B12/C) in polymer-electrolyte fuel cells (PEFC).[1, 2]

These authors proposed that B12/C has a promising performance and great stability for use in the cathode of a PEFC. Vitamin B12 contains the biochemically rare element cobalt (Co), which is connected to four nitrogen atoms and two axial ligands as presented in Fig. 1. For vitamin B12 as a transition-metal macrocyclic compound, the ORR activity is dominated by the oxidation state of the central transition metal Co and the redox potential of Co. They demonstrated that the

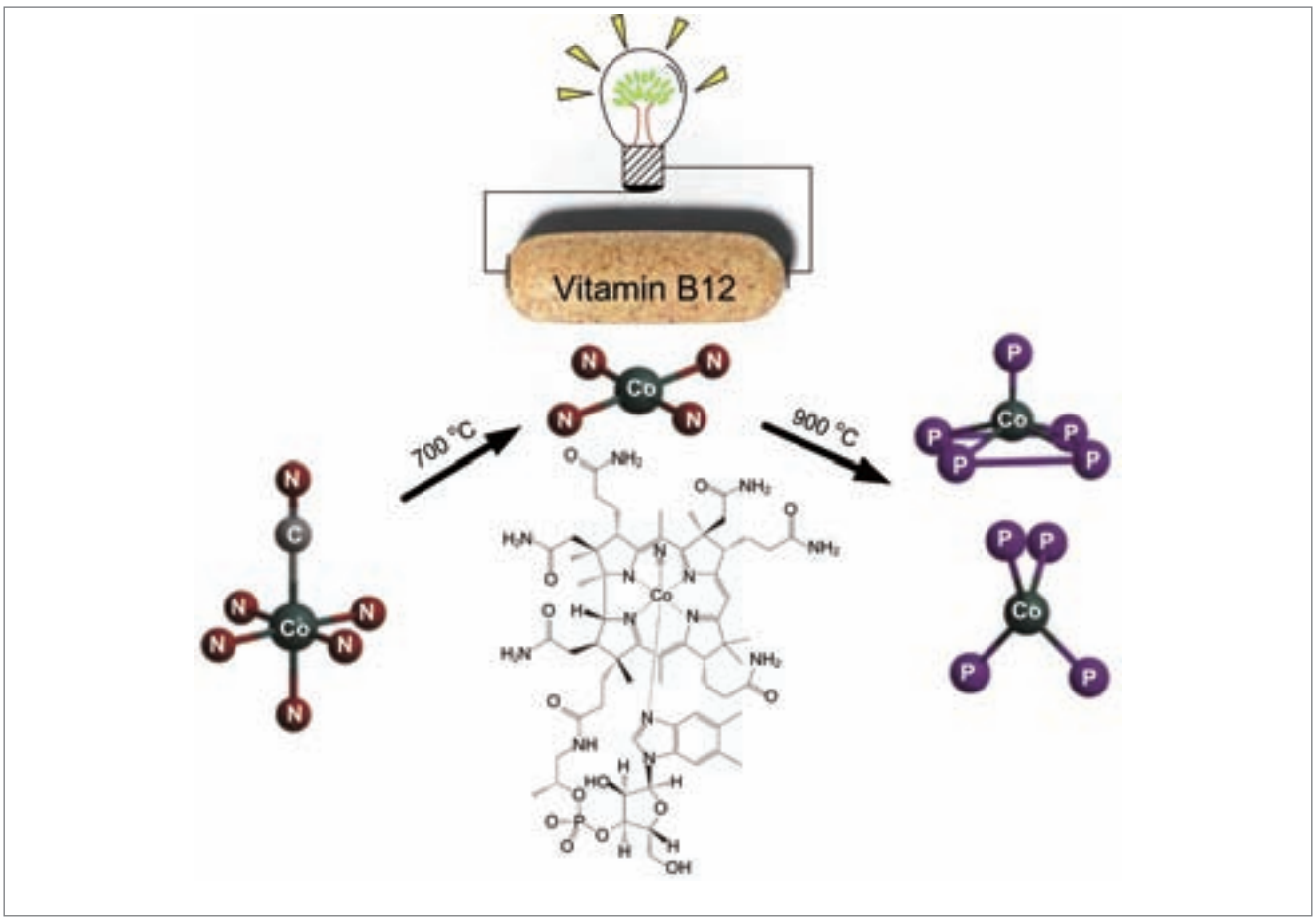

Fig. 1: The molecular structure of vitamin B12 and its changes during the pyrolysis. This figure is adapted from Ref. 2.

Co coordination number changes from 6 to 4 (octahedral structure to square-planar structure) during the pyrolysis from the results of X-ray absorption near-edge structure (XANES) and extended X-ray absorption fine structure (EXAFS) obtained from beamline **BL17C** at NSRRC. The square-planar structure of four coordinated Co (Co-N4 chelate) carried out at pyrolysis temperature at 700 °C provided excellent performance for catalyzing ORR in the PEFC composed of a pyrolyed B12/C cathode. When the Co ion reacted with the hydrogen phosphate ion at the pyrolysis temperature of 900 °C, the square-planar structure transferred into a tetrahedral or pyramidal structure of Co_2P, resulting in a loss of ORR activity. Large current and power densities and great durability after 100 h were also observed in a test of the vitamin B12 fuel cell.

References

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2. S. T. Chang, H.-C. Hsu, H.-C. Huang, C.-H. Wang, H.-Y. Du, L.-C. Chen, J.-F. Lee, and K.-H. Chen, Int. J. Hydrogen Energ. **37**, 13755 (2012).