Electrical energy generation at hydrothermal environments in the Solar System estimated by fuel cell model experimentations

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A prime consideration for habitability of planets and moons is to constrain available free energy provided in the environment that could support the extant life and/or could drive chemical evolution. On Earth, primary production of a biosphere have been considered to be supported by phototrophs and chemotrophs with light and chemical energy, but recent studies discovered prokaryotes defined as electrotrophs that are capable of using electrons provided by artificial electrodes as the sole energy source for cellular activities [1]. This suggests that electrical energy could support the formation and evolution of a biosphere, and requires us to consider electrical energy, in addition to light and chemical energies, provided at the environment to estimate the habitability.

Although we have not yet had direct evidence for an electrotrophic ecosystem in a natural setting, spontaneous electrical current through conductive minerals and microbial matrixes that could support a life have been observed in sea floor environments on Earth. A promising example for spontaneous electrical energy generation is the marine hydrothermal environments in which conductive mineral deposits chemically separate hydrothermal fluid and sea water. Studies demonstrated that a marine hydrothermal system being functioning as analogous to a fuel cell generating power where sulfide deposit couples electrochemical oxidation of sulfide in the hydrothermal fluid and reduction of dissolved oxygen in the sea water with its electrocatalytic activity and electrical conductance [2].

As moons in the Solar System such as Enceladus and Europa are suggested to possess oceans with hydrothermal activity, it is hypothesized that those hydrothermal systems also generate electrical energy that provide free energy capable of supporting a biosphere. The present study is to estimate potentials of electrical energy generation at hydrothermal systems in oceans of the Solar System with laboratory electrochemical model experiments reproducing hydrothermal systems. Namely, electrochemical characterizations were conducted by using electrodes covered by sulfide minerals simulating hydrothermal deposits with electrolytes simulating hydrothermal fluids and seawaters. This presentation discusses electrocatalytic properties and potential power production of simulated hydrothermal systems with results of voltammetry tests and fuel cell polarization tests.

References: [1] Kumar, A. et al., (2017) Nature Reviews Chemistry 1, 0024. [2] Yamamoto, M. et al., (2018) ChemElectroChem 5. 2162-2166.

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