# Designer Materials to Unveil Microscopic Mechanisms of Energy Storage/Conversion Electrode Processes

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Understanding highly complicated electrode processes is not only a key in basic science, but also important for industrial technology development. This is even more important in the 21st century since the anomalous demands for sustainable production of electrical energy. Therefore, huge efforts to disclose reaction mechanisms in electrochemical "black boxes" is highly important, especially for complicated reactions in key energy conversion/storage systems using sustainable materials, such as carbon-based electrocatalysts or strategically designed metal/organic hybrid electrodes.[1] This is because these newly developing materials, being expected as next-generation electrode materials, often show different features compared to well-known traditional materials, such as noble metals or oxides. In order to understand aforementioned electrode processes, rationally-designed materials, i.e. "Designer Materials" are applied as model systems.[1,2] Because basic principles of electrochemical reactions are strongly linked to electron-transfer steps, these designer materials could enable to control electrode processes by tuning their electronic properties led by own designer structures.[3]

In my talk, I will show that an electrode process study based on rationally-designed materials is a powerful approach for deep understandings of complicated mechanisms of next-generation (and sustainable) electrode materials. Especially, electronic-active frameworks, such as carbon-, nitrogen- (C-, N-) based frameworks, can be tuned their chemical and geometrical structures. Therefore, these material systems can be suitable model systems to unveil complicated microscopic mechanisms of energy storage/conversion reactions working at non-traditional materials.

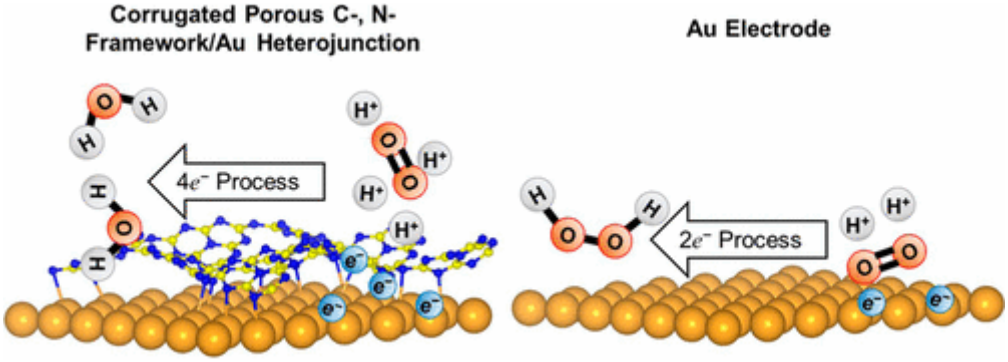
I will talk three topics below:

**1.** Metallically conductive metal-organic framework (MOF) as mode electrode materials to understand the energy storage principle based on intercalation mechanism.[4]
**2.** A carbon–nitrogen-based two-dimensional porous framework/metal heterojunction strategy

as a model system of carbon-based electrocatalysts (Figure).[3]

**3.** Microscopic ORR electrode process in highly active N-doped carbon catalysts.[5]

I wish that the works shown above provide the approach and view for creating highly efficient electrode materials and the knowledge on microscopic processes of complicated multielectron transfer reactions using newly developing materials, thereby leading to understand mechanisms of key energy storage/conversion reactions.





1) a) K. Sakaushi, M. Antonietti, *Acc. Chem. Res*. **2015**, *45*, 1591. b) K. Sakaushi "Two-Dimensional Organic and Hybrid Porous Frameworks as Novel Electronic Material Systems: Electronic Properties and Advanced Energy Conversion Functions" In *Functional Organic and Hybrid Nanostructured Materials: Fabrication, Properties, and Applications*, Q. Li (Ed.), Wiley-VCH, Weinheim, 2018, 419.
2) a) S. Kitagawa, R. Kitaura, S. Noro, *Angew. Chem. Int. Ed*. **2004**, *43*, 2334. b) A. G. Slater, A. I. Cooper, *Science* **2015**, 348, aaa8075. c) C. S Diercks, O. M. Yaghi, *Science* **2017**, 355, eaal1585.
3) K. Sakaushi, A. Lyalin, S. Tominaka, T. Taketsugu, K. Uosaki, *ACS Nano* **2017**, *11*, 1770.
4) K. Wada, K. Sakaushi, S. Sasaki, H. Nishihara, *Angew. Chem. Int. Ed.* **2018**, DOI: 10.1002/anie.201802521.
5) K. Sakaushi, R. J. Behm et al., *manuscript submitted*.