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Photocatalytic challenge of carbon dioxide conversion into fuels supported by spectroscopy

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Photocatalytic conversion of CO_2 into fuels explores a route to carbon-neutral fuels, avoiding the net increase in atmospheric CO_2 concentrations associated with fossil-derived alternatives.[1] Intensive studies have been reported for the CO_2 photoconversion, however, the development of good catalyst, the optimization of reaction conditions, and the understanding of efficient photocatalytic mechanism are still required for the future applications.[2]

As a new type of photocatalysts for the CO_2 photoconversion, we previously investigated layered double hydroxides (LDHs), typically comprising Zn, Cu, and Ga/Al to form methanol.[3] The doping of Ag nanoparticles on/in Zn_3Ga LDH was effective to enhance the selectivity to methanol (54 mol%) under the irradiation of UV–visible light and also the photoformation rates of CO and methanol under visible light only while Au doping was ineffective.[4] The reason was explained based on the excitation of Ag/Au nanoparticles by visible light and that of LDH by UV light (Figure 1). Due to the level difference of conduction band of LDH and hot electrons at Ag/Au nanoparticles, effective electron flow finally to CO_2-derived species was enabled from Ag to Zn_3Ga LDH as monitored by X-ray absorption fine structure (XAFS) and UV–visible spectroscopy.

Pretreatment and photocatalytic reaction conditions were investigated for $Zn_{3-x}Cu_xGa$ LDHs (x = 0, 1.5). If the catalyst was preheated at 423 K and protected in argon, total formation rates of methanol and methane increased to 2.7 μmol h^{-1} g_{cat}^{-1} at 0.40 MPa of CO_2 and H_2 gas due to the liberation of interlayer reaction space of LDH by removing one third of interlayer water molecules as monitored by XAFS.[5] At the lecture, related recent progresses are also discussed.

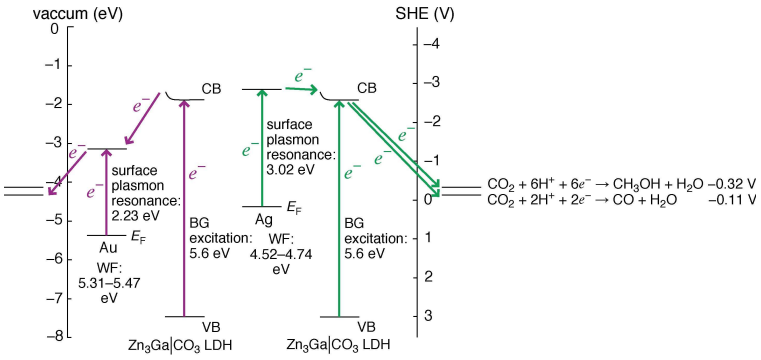

Figure 1. Energy levels for Ag/LDH and Au/LDH photocatalysts and CO_2 reduction reactions.[4]

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Curriculum VITAE

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Education & Jobs

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Representative papers

1	"Solar cell for maximizing voltage up to the level difference of two photocatalysts: optimization and clarification of electron pathway", M. Yoshiba, Y. Ogura, M. Tamba, T. Kojima, Y. Izumi, *RSC Advances*, **7**, 19996–20006 (2017)
2	"Efficient Volcano-type Dependence of Photocatalytic CO_2 Conversion into Methane Using Hydrogen at Reaction Pressures up to 0.80 MPa", S. Kawamura, H. Zhang, M. Tamba, T. Kojima, M. Miyano, Y. Yoshida, M. Yoshiba, Y. Izumi, *Journal of Catalysis*, **345**, 39–52 (2017)
3	"Recent advances in the photocatalytic conversion of carbon dioxide to fuels with water and/or hydrogen using solar energy and beyond", Y. Izumi, *Coordination Chemistry Reviews*, **257**, 171–186 (2013)
4	"Photocatalytic Conversion of Carbon Dioxide into Methanol using Zinc-Copper-M(III) (M = Aluminum, Gallium) Layered Double Hydroxides", N. Ahmed, Y. Shibata, T. Taniguchi, Y. Izumi, *Journal of Catalysis*, **279**, 123–135 (2011)
5	"Site Structure and Photocatalytic Role of Sulfur or Nitrogen-Doped Titanium Oxide with Uniform Mesopores under Visible Light", Y. Izumi, T. Itoi, S. Peng, K. Oka, Y. Shibata, *Journal of Physical Chemistry C*, **113**, 6706–6718 (2009)
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