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Hydrothermally fabricated 3-D nanostructure metal oxide sensors

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Hierarchical nanostructures with higher dimensionality, consisting of nanostructure building blocks such as nanowires, nanotubes, or nanosheets are very attractive. They hold great properties like the high surface-to-volume ratio and well-ordered porous structures, which can be very challenging to attain for other mono-morphological nanostructures. Well-ordered hierarchical nanostructures with high surface-to-volume ratios facilitate gas diffusion into their surfaces as well as scattering of light. Therefore, hierarchical nanostructures are expected to perform highly as gas sensors.

A multistage controlled hydrothermal synthesis method to fabricate high performance single ZnO brush-like hierarchical nanostructure gas sensor from initial nanowires is reported. The performance of the sensor based on brush-like hierarchical nanostructure is analyzed and compared to that of a nanowire gas sensor. The hierarchical gas sensor demonstrated high sensitivity toward low concentration of acetone at high speed of response. The enhancement in the hierarchical sensor performance is attributed to the increased surface to volume ratio, reduction in dimensionality of the nanowire building blocks, formation of junctions between the initial nanowire and the secondary nanowires, and enhanced gas diffusion into the surfaces of the hierarchical nanostructures.

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Particulate photocatalyst sheets for efficient and scalable solar hydrogen production via water splitting

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Photocatalytic water splitting driven by solar energy has been studied extensively as a means of renewable hydrogen production on a large scale. A solar-to-hydrogen energy conversion efficiency (STH) of 5% or higher is considered to be necessary for practical operation of photocatalytic solar hydrogen production. To attain such a high STH at reasonable quantum efficiencies, it is necessary to activate and stabilize narrow band gap semiconductor photo-catalysts. Scalability of the system is also an important concern. In this regard, development of particulate photocatalysts that are active in the water splitting reaction without an external power supply is important. Recently, the author's group has studied photocatalyst sheets based on particulate hydrogen evolution photocatalyst (HEP) and oxygen evolution photocatalyst (OEP) embedded into conductive layer by particle transfer for efficient and scalable water splitting. The STH of pure water splitting using photocatalyst sheets consisting of La- and Rh-codoped $SrTiO_3$ ($SrTiO_3$:La,Rh) as a HEP and Mo-doped $BiVO_4$ ($BiVO_4$:Mo) exceeds 1.1% superior to those for corresponding powder suspension systems. The high activity of the photocatalyst sheet is due to the underlying conductive layer allowing for the efficient electron transfer between HEP and OEP particles. In addition, evolution of hydrogen and oxygen in close proximity allows preventing generation of pH gradient during the water splitting reaction. However, the absorption edge wavelengths of $SrTiO_3$:La,Rh and $BiVO_4$:Mo are 540 nm at most. It is still important to develop photocatalysts with longer absorption edge wavelengths. In my talk, recent progress and future challenges in photocatalytic water splitting and system development will be presented.

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