Catalytic Plasmonic Ribbon™

The manufacture of industrial chemicals is largely achieved by catalysis, where the presence of catalytic material will lower the energy required for the chemical reaction to proceed without being consumed in the process. DOE statistics show that catalysts are used in 90% of U.S. chemical manufacturing processes and in making over 20% of all industrial products. However, these established processes are still energy intensive and costly. Aquaneers Catalytic Plasmonic Ribbon™ represents a new approach to catalytic chemical synthesis using optical power and "plasmonic enhancement" to reduce the cost and energy requirements for producing important chemicals like methanol or ammonia from sustainable sources.

The utilization of carbon dioxide (CO_2) as an industrial feedstock for fuel production, as opposed to the overgeneration of CO_2 from fossil fuel usage, represents a path to energy sustainability with reduced environmental impact. Aquaneers is developing an innovative catalytically active form of its Plasmonic Ribbon™ product to demonstrate the synthesis of methanol (CH_3OH) from CO_2 and hydrogen (H_2) gases using a novel optically powered flow-reactor. This work is supported by a new Phase I SBIR grant from the DOE (DE-SC0019657). Aquaneers leads the SBIR project in collaboration with New York University, Brookhaven National Laboratory, and the University of South Carolina NSF Center for Rational Catalysis. The team will fabricate Catalytic Plasmonic Ribbon™ and determine its functionality in promoting photocatalytic chemical synthesis.

Aquaneers Plasmonic Ribbon™ is comprised of metallic nanorod arrays engineered on the surface of flexible Corning® Willow® Glass using roll-to-roll manufacturing techniques. When illuminated in the vicinity of the nanorods plasmon resonance energy (frequency), light is absorbed with extraordinary efficiency. This optical energy is transduced into heat and energetic charge carriers (electrons and holes) at high densities within the tiny nanorods. The localized heating and chemically active charges provide the "plasmonic enhancement" utilized to facilitate chemical transformations of adsorbates on the surfaces. When the surface is catalytically tailored for targeted chemical species, the plasmonic interaction will lower the activation energy and allow chemical synthesis to proceed more efficiently.

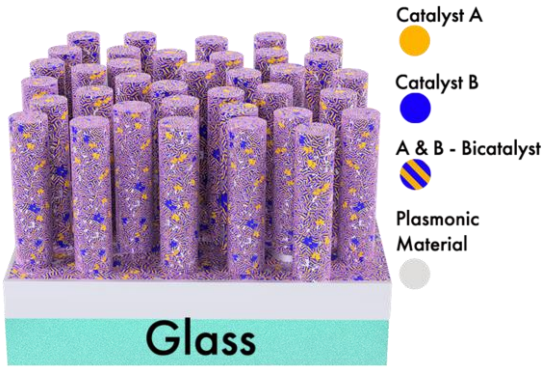

Figure 1. Catalytic Plasmonic Ribbon™ is produced by coating the nanorods with a two-component catalytic material.

Catalytic Plasmonic Ribbon™ is produced by coating the nanorod arrays of the nanomaterial with a thin layer of catalyst. Figure 1 shows a schematic representation of Aquaneers Plasmonic Ribbon™ coated with a bi-catalytic layer to facilitate the synthesis of methanol from CO_2 and H_2 ($CO_2 + 3H_2 \leftrightarrows CH_3OH + H_2O$). When a CO_2 molecule is adsorbed, Catalyst A acts on the carbon, while Catalyst B acts on the oxygen, resulting in a weakened C=O bond that makes reducing the molecule easier. The plasmonically induced localized heating and energetic charges react with the weakened C=O bond and H_2 molecules adsorbed on the catalytic nanorod surface to dissociate the molecules and create a C–H bond that subsequently leads to methanol formation. The bicatalytic surface acts in combination with plasmonic energy conversion to lower the activation energy of chemical reactions. This "plasmonic enhancement" can lead to dramatic reductions in energy

Contact: Joe Habib / jhabib@aqunaeersinc.com
710 Parkside Ave. Brooklyn, NY 11226 (646) 725-7232
www.aquaneersinc.com

consumption and the closely related cost of production for important industrial chemicals, pharmaceuticals, and other products.

To demonstrate the photocatalytic utilization of CO_2 for methanol synthesis, Aquaneers employs a shallow, flat-bed reactor designed for industry standard gas-phase photocatalysis as shown in Figure 2. The reactor body is made of stainless steel with O-ring seal and has a hermetically sealed fused quartz window to operate at pressures up to 12 Bar with gas distribution and collection manifolds to increase uniformity and decrease stagnant zones.

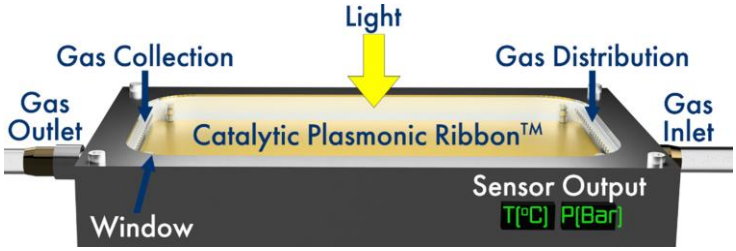

Figure 2. Aquaneers photocatalytic Flow Reactor for performing chemical synthesis using optical energy.

Aquaneers seeks to demonstrate the synthesis of important chemicals that command large markets and consume huge quantities of energy in their manufacture. Methanol is one of the top ten industrial chemicals used today and is primarily produced by the catalytic hydrogenation of carbon monoxide sourced from synthesis gas. In 2014, global methanol production was 75 million metric tons, which should increase to 133 million metric tons by 2020. Methanol was a $55 Billion global industry in 2015, while the complimentary market for catalytic materials used in global methanol production was $288.7 million. It is used in the manufacture of many consumer products and is a widely used fuel source. It is a feedstock to produce numerous chemicals such as acetic acid and formaldehyde, which in turn are used in products like adhesives, foams, plywood subfloors, solvents and windshield washer fluid.

Aquaneers Inc. was founded January 2016 in Brooklyn, NY and incorporated as a Delaware C-Corporation. Located in the SUNY Downstate Incubator, Aquaneers is a certified START-UP NY business. The company has received SBIR Phase I and Phase II grants of $1.3M total from the Dept. of Energy to perform R&D into manufacturing plasmonic nanomaterials for solar energy conversion and the photocatalytic utilization of carbon dioxide for methanol synthesis.

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