Carbon Capture and Recycling by photocatalysts supported on Silica Nanosprings™

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Greenhouse Gas mitigation is seen as a necessity by both the USA and the international community. Carbon capture, separation, and storage(CCS) is the most common method in which CO_2 is used for oil and gas recovery, coal bed methane production, or storage in saline formations. GoNano Technologies Inc. is currently developing Carbon Capture and Recycling technology as an alternative and/or a complement to the CCS technology. CCR involves the conversion of captured or emitted CO_2 into useful products such as formic acid, formaldehyde or formic acid [1]. This system is designed to require minimal modification to actual industry and power plant emission stacks to reduce the cost of implementation. In addition, the use of solar light or high energy efficiency UV LED lights to bring about this conversion will provide lower energy penalties.

GoNano's approach to photo-reduce CO_2 is based on TiO_2 nanoparticles immobilized on silica Nanosprings™, [2], a high surface area advanced nanomaterial(fig 1). BET measurements of silica Nanospring mats reveal a surface area of 400 m^2/g, which is equivalent to 1500 cm^2 per cm^2 of footprint. Anatase TiO_2 coating by Atomic Layer Deposition(fig 2) on the Nanosprings reduces the overall surface area to 250 m^2/g, but still have approximately 4 times the surface area of the commercially available Degussa P25 TiO_2 nanoparticles(fig 3).

The CCR system utilizes a solar panel like reactor that has the photocatalyst mat inside and a quartz window to allow for solar light and UV light irradiation. The assessment of the CO_2 conversion is done by two types of reactions:

A) CO_2 reduction into methanol.

A flow of CO_2 dissolved in water at RTP is introduced into the reactor (solution flow rate into the reactor ~ 0.5 ml/hr). UV light(A 50 W solar simulator Hg lamp. AM 1.5) is incident through a quartz window. 0.1 ml samples from the outlet,are analyzed by a Flame Ionization Detector (150^{o}C with He Carrier gas at 30 ml/min) on a HP5890 Series II Gas Chromatograph. Conversion efficiency in the range 3-5% of dissolved CO_2 being converted into methanol (fig 4), after 3 hours of the light shining on the photo catalyst have been observed. The Space Time Yield is 4.21 mmol/(g cat.h) which is high compared to µmol/(g cat.h) ranges from commercially available Degussa P25 TiO_2 catalyst [3].

B) CO_2 reduction into Formaldehyde and Formic Acid in presence of Methanol.

Keeping all the reaction conditions the same, addition of 1% methanol into the reaction mixture, dissolved CO_2 conversion efficiencies of 12% into formaldehyde(72.3%) and formic acid(27.7%) have been measured(fig 5).

These results indicate that the CCR technology is capable of selectively reducing CO_2 into products. Enhancing the conversion efficiencies with interface engineering of the photocatalyst is now being pursued.

[1] T. Inoue, et al. “Photoelectrocatalytic reduction of carbon dioxide in aqueous suspensions of semiconductor powders,” Nature, 277, 637 ,1979.
[2] D.N. McIlroy, A. Alkhateeb, D. Zhang, D. E. Aston, A. C. Marcy, and M. G. Norton, J. Phys.: Condens. Matter, vol. 16, no. 12, pp. R415-R440, 2004.
[3] I. Tseng, “Photoreduction of CO_2 using sol–gel derived titania and titania-supported copper catalysts,” Applied Catalysis B: Environmental, vol. 37, no. 1, pp. 37-48, 2002.

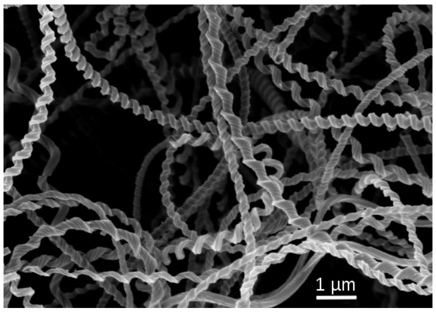

Fig 2 FESEM image of Nanosprings

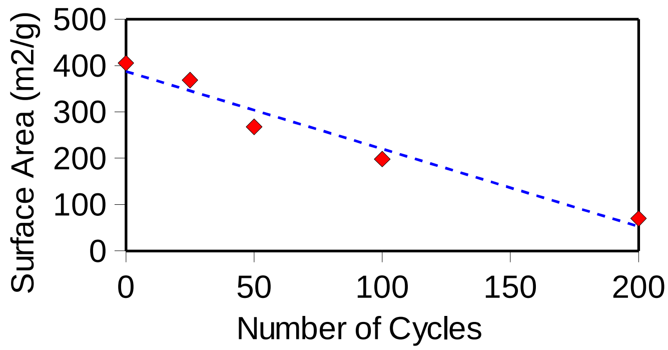

Fig 1: BET Surface area measurements

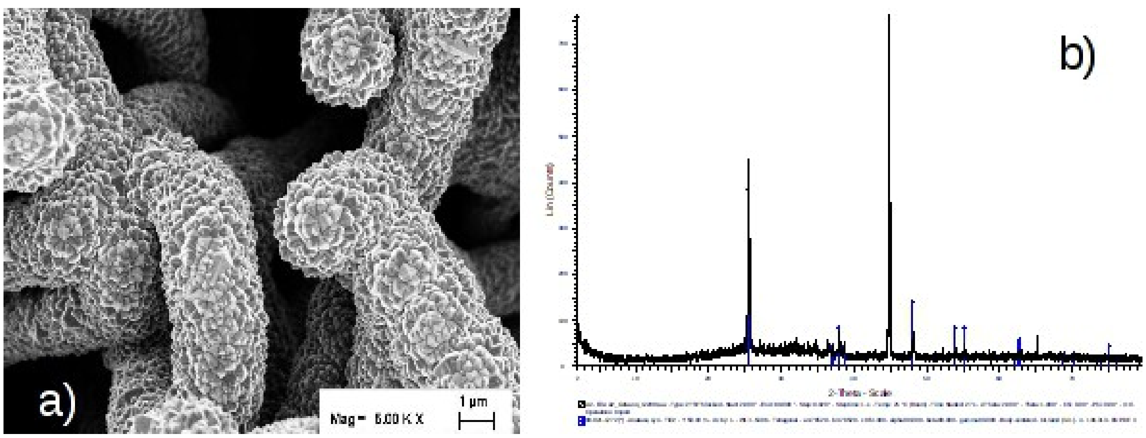

Fig 3. HRTEM image of Nanosprings coated with TiO_2 by ALD and XRD indicating anatase TiO_2

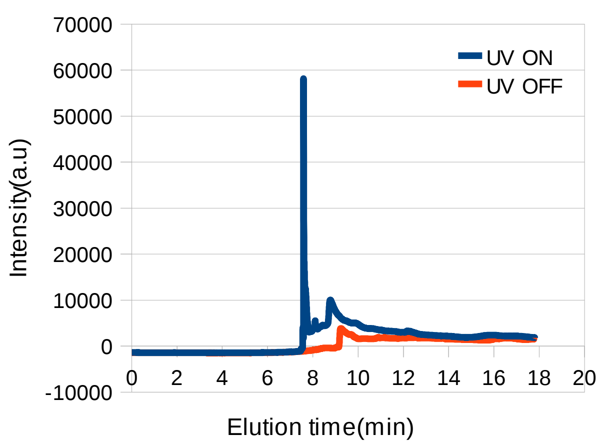

Fig 4: Chromatogram indicating 3.17% conversion of dissolved CO2 into Methanol

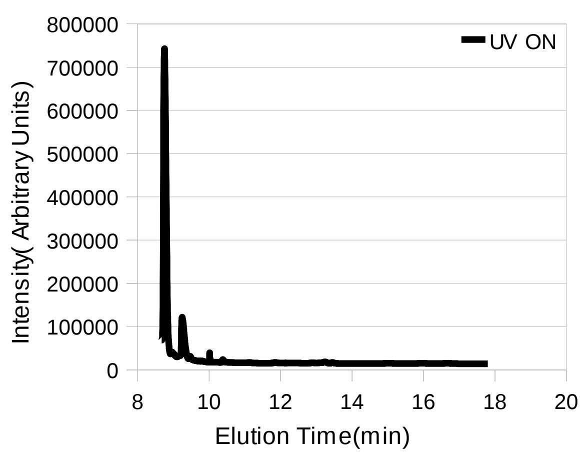

Fig 5: Chromatogram indicating 12% conversion of dissolved CO2 into HCHO and HCOOH

Topic Area: CO_2 Reduction & Management