Small Scale Demonstration of Plasmonic Photocatalysis in Direct Air CO2 Capture

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Direct Air CO2 Capture (DAC) is a critical technology for generating negative emissions to reduce atmospheric CO2 concentrations to preindustrial levels by 2050. One of DAC's most significant challenges is related to the high energy costs that make up 80% of the total operating costs for traditional thermal swing systems. Our approach explores an alternative method, delivering localized heat rather than bulk heat using titanium nitride (TiN) nanoparticles as light absorber. Specifically, the plasmonic photocatalyst TiN is integrated with a polyethylenimine (PEI) solid CO2 sorbent on an alumina support structure as photo-swing desorption method has shown to desorb similar levels of CO2 than thermal-swing desorption. This study aims to scale up a previously demonstrated photo-swing DAC laboratory benchtop setup into a standalone device by increasing contactor surface area and incorporating a turbine to facilitate air transport, and hence adsorption. The device is designed and constructed with integrated energy-efficient LEDs to allow the illumination of the TiN light absorber, turning irradiated energy into highly localized heat through plasmonic processes. Performance related to DAC will be evaluated across multiple adsorption/desorption cycles, and cycle timings will be varied to find an optimal balance between energy input and CO2 desorbed. If successful, this approach could inform the opportunity space of DAC technologies ranging from small to large scale deployment.

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