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Quantum Yield Optimization for Semiconductor Photocatalysis Systems

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Design and Build of a Photocatalytic Reactor

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Introduction

The utilization of photocatalysis has well-known potential for the degradation of organic contaminants in water purification processes [1]. A continuous flow photocatalytic reactor was developed in order to optimize the quantum yield of titanium dioxide (TiO_2,) a semiconductor material well known for its photocatalytic properties [2]. This photocatalytic reactor was particularly designed for a controlled, variable radiant flux of ultraviolet (UV) light onto a fixed 3-dimensional thin-film catalyst structure. An exploded-view solid model representation of the UV chamber and a transparent view are shown below in Figure 1, parts a) and b) respectively.

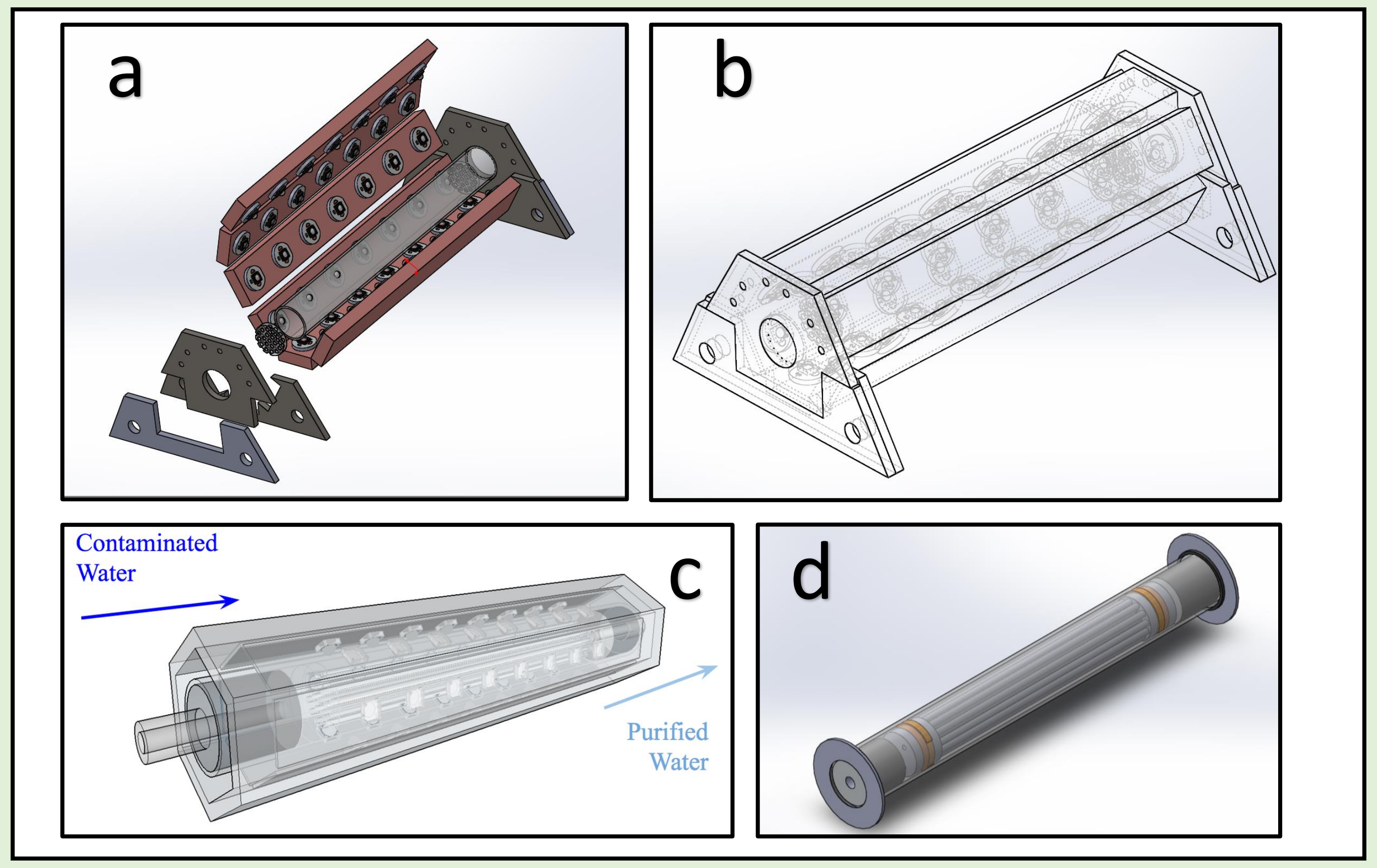

Figure 1. Solid models of the UV chamber (a, b) and the catalyst reactor core (c, d) [3]

Continuous UV radiation excites the photocatalyst, generating electron-hole pairs that form hydroxyl radicals. The design of the reactor includes a variable catalyst cartridge (shown above in parts c) and d) of Figure 1), allowing multiple catalyst thicknesses, positions, and phases to be tested in rapid succession. In having these controlled variables, this reactor allows for a consistent measurement of contaminant degradation, relating directly to the quantum yield of the catalyst. Results from testing are to be compared to a theoretical model developed to optimize catalyst geometry based on electron-hole pair generation and diffusion processes.

Reactor Build

There are three parts to this work: UV chamber and control system, catalyst cartridge assembly, and material synthesis. The reactor UV chamber consists of six illumination walls, each with high-powered UV-LEDs mounted within. The intensity of UV exposure to the catalyst is controlled by pulse-width-modulation on a touchscreen display. Below, Figure 2 shows multiple views of the reactor. 2b) shows the illumination of the UV chamber core, while 2d) shows the reactor core.

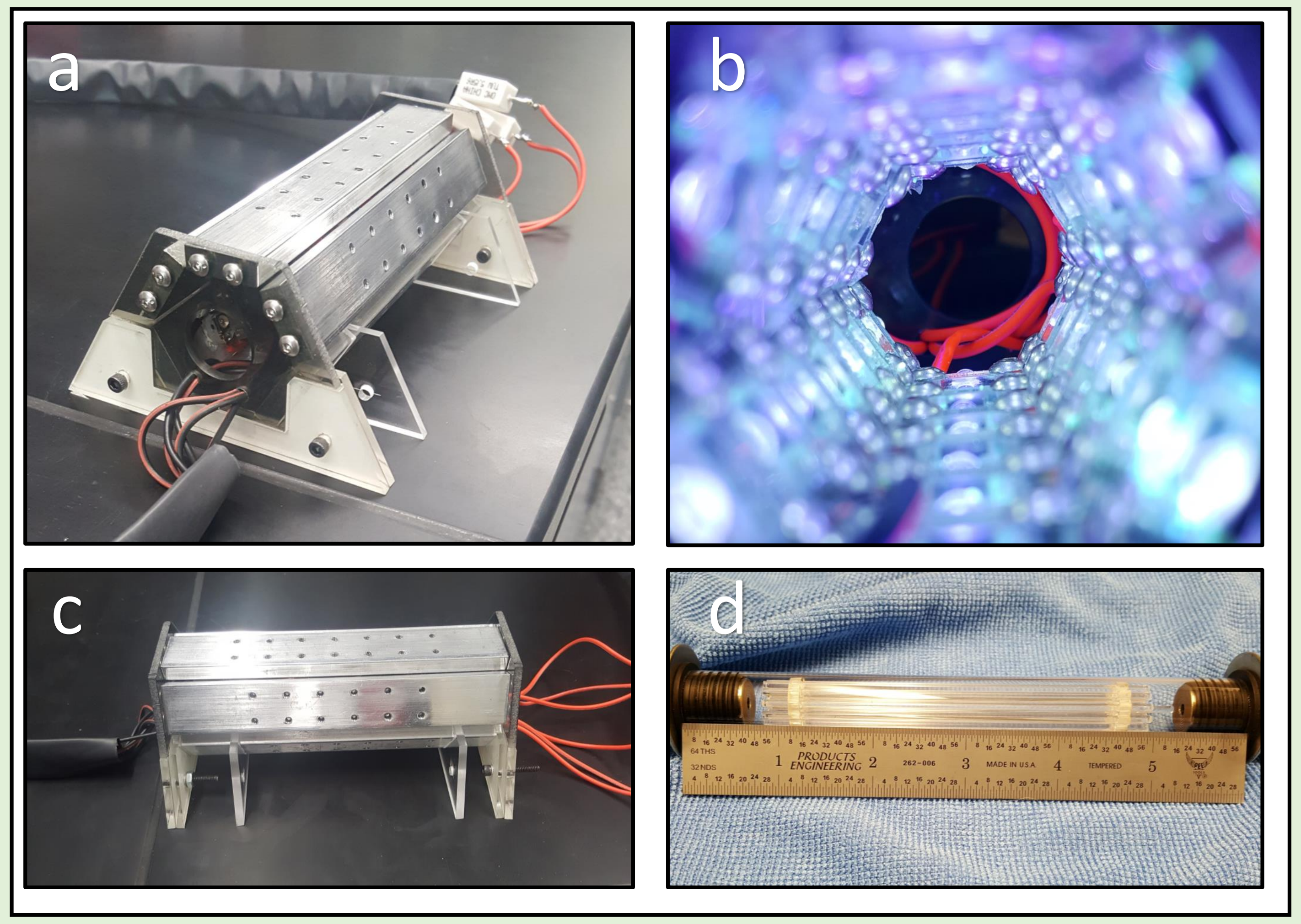

Figure 2. Images of the UV chamber (a-c), and the catalyst reactor core (d).

Material Synthesis

Synthesizing the TiO_2 catalyst onto the quartz substrate is an important aspect of this work. Prior to catalyst cartridge syntheses, a material synthesis procedure is to be finalized. A sol-gel dipping process is being used to establish a TiO_2 thin film with the highest catalytic activity. To characterize the synthesized films, multiple analytical tools such as scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS), Raman spectroscopy and UV-Vis spectroscopy were used.

Results

For the initial contaminant degradation testing, Methylene Blue (MB) is used as a model contaminant. A single UV-LED is used to photo-activate TiO_2 on quartz within a cuvette, degrading surrounding MB over time. Degradation measurements are performed with a Shimadzu UV-Vis 3600 Spectrophotometer. Experimental procedure and degradation results of initial testing is shown in Figure 3.

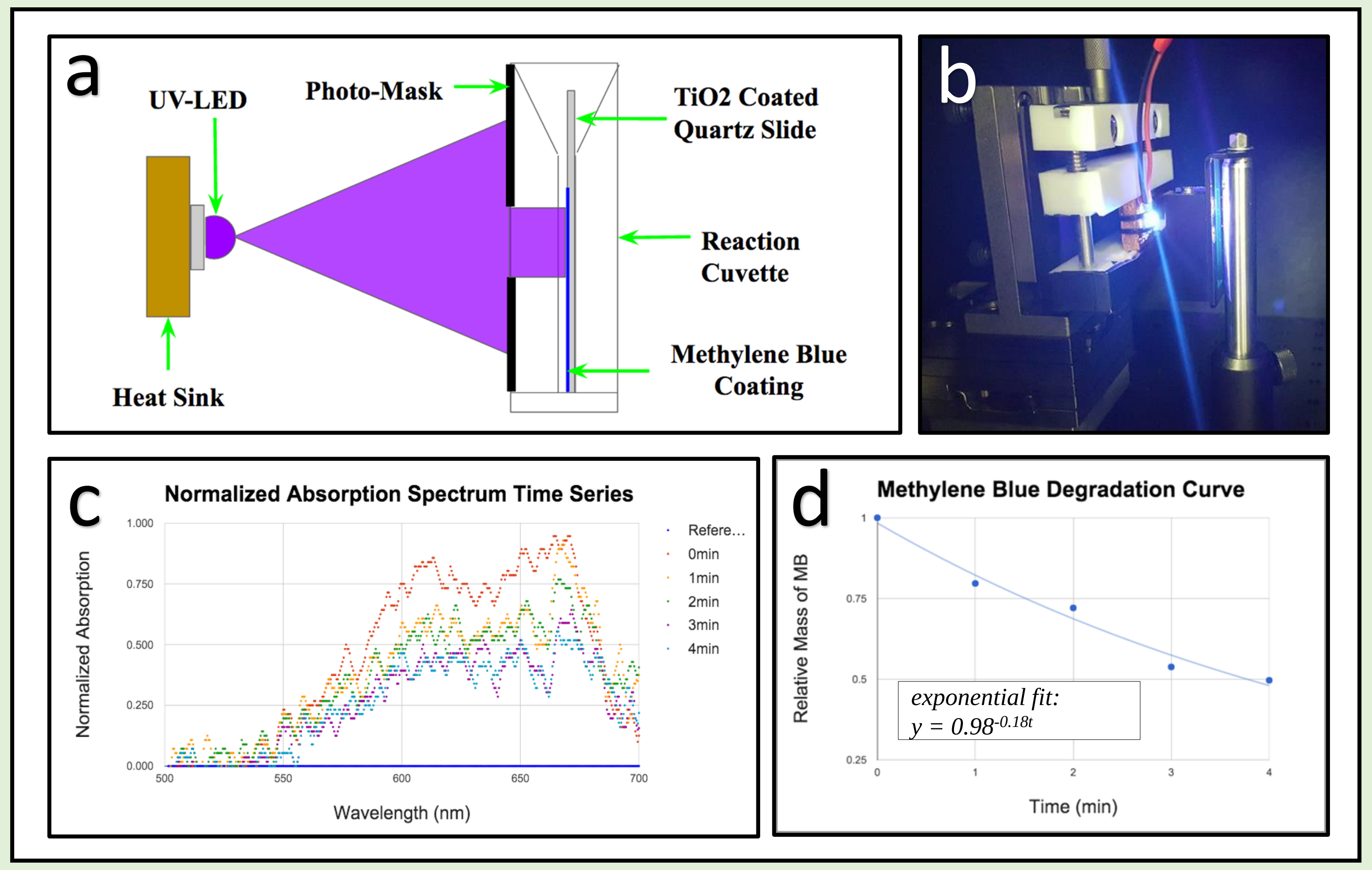

Figure 3. Experimental procedure and depiction for initial catalyst testing is shown in (a) and (b). UV-Vis data shows the degradation of the MB over time in (c) and (d). Depiction and data is from previous testing done by the same group [3].

Future Work

The next steps of this research include the following: finalizing the material synthesis process, establishing the control and degradation measurement systems, and testing the system for continuous flow degradation.

References

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