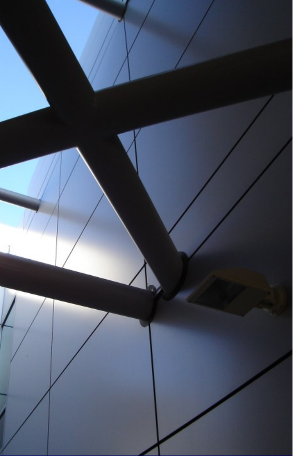

MECHANICAL ENGINEERING

DISSERTATION DEFENSE

*The Department of Mechanical Engineering presents:*

# *The Ph.D. Dissertation Defense of*

# *Kairui Xia*

**Friday, July 22, 2022, 10AM Pacific**

## A Study of a Novel Photocatalytic Microreactor for Water Purification

Doctor of Philosophy, Graduate Program in Mechanical Engineering
University of California, Riverside, July 2022
Dr. Masaru Rao, Chairperson

Exploring the vast space has always been one of the greatest dream for all human beings. The International Space Station (ISS) is currently working as a test platform for experimenting various essential equipment for further deep-space exploration and colonization. Because of limited space for storing water on ISS, Water Recovery System (WRS) is heavily depended to produce recycled drinkable water from collected wastewater. As one important component of WRS, the thermal catalytic reactor is designated to remove all Volatile Organic Compounds (VOCs) which is difficult to be dissolved by other treatments. However, the high temperature and pressure working environment makes some of its fragile parts need continuous replacements leading to increased cost and potential risks.

Herein, we propose a photocatalytic microfluidic reactor (PMFR) which can be operated at normal temperature and pressure to replace the thermal catalytic reactor. For this titanium (Ti) PMFR, micropillar arrays covered with nanoporous titania (NPT) are designed to attain increased surface area to volume ratios, reduced diffusion lengths, and greater uniformity of irradiation. For the first time, the microelectromechanical systems (MEMS) techniques are used to fabricate a Ti-based microfluidic reactor. For the first degradation study with organic dye Methylene Blue, the micropillar reactor (MP) was found to dramatically outperform its planar counterpart and the 50 μm deep MP (MP50) presented at least two times higher degradation activity than other reported PMFRs. The second study introduced a VOC half-life estimation model designed based on the steady-state concentration of hydroxyl radicals (·OH). This radical was considered as the main reactant of the photocatalytic degradation of VOCs, and its concentration was measured by using nitrobenzene as probe. Half-lives for all VOCs existed in the Ersatz wastewater proposed by NASA were estimated, and results indicated that the MP50 was capable of dissolving most of these VOCs at or under around 100 seconds. The third and last study looked into the MP50 degradation performance with two common stubborn VOCs – ethanol and 1,4-dioxane. Results showed that MP50 eventually fully mineralized about 11.78% of ethanol. As for 1,4-dioxane, MP50 successfully degraded around 78.83% of it with a reaction rate constant two to three orders of magnitude higher than that of other bulk reactors reported in literatures. These findings demonstrate a great potential for the micropillar PMFR to replace thermal catalytic reactor on ISS and even be used for more varieties of water purifications.