Master's Thesis Engineering Technology

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Characterization and optimization of the translucent monolithic photoreactors and comparison with other photoreactors

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Introduction

Photochemical reactions have a couple of advantages compared to thermochemical reactions such mild reaction conditions, higher selectivity, and access to new reaction pathways [1], [2]. Despite these advantages, photochemical reactions are rarely used in industry due to the limited scalability, caused by the photon transfer limitations.

It is hypothesized that a new reactor design can overcome these limitations by utilizing microchannels arranged in an organized structure. This reactor design is the translucent monolithic reactor. The purpose of this research is to characterize the translucent monolithic reactor and compare it to other competitive photochemical reactors.

Methods

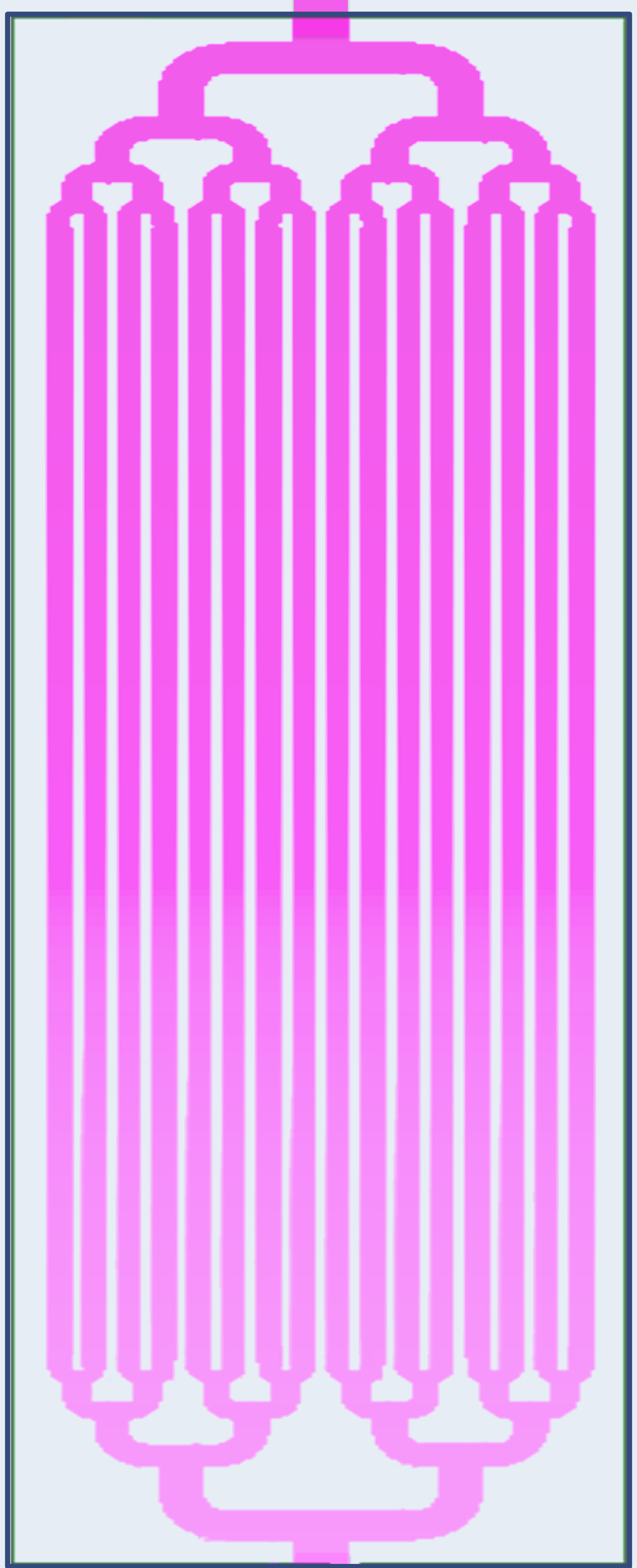
First, the influence of power, flow rate and concentration on the conversion, reaction rate, Space-time yield (STY) and photochemical space-time yield (PSTY) were studied based on a model reaction with DPA to find the optimal working conditions for the monolithic reactors. With STY being the measurement of productivity and PSTY is a measurement of energy efficiency of a photoreactor. The ranges of these settings are given in Table 1 and the differences in dimensions between the monolithic reactors are given in Table 2.
Then The monolithic reactors were tested at these conditions and compared to other competitive photoreactors.
Finally, attempts were made to achieve slug flow within the monolithic reactors

Table 1: ranges of studied parameters

Parameter	Minimum	Maximum
$I_{LED's}$ (A)	0,1	0,6
Q (ml/min)	5	50
Conc Rose Bengal (RB) (µM)	100	300

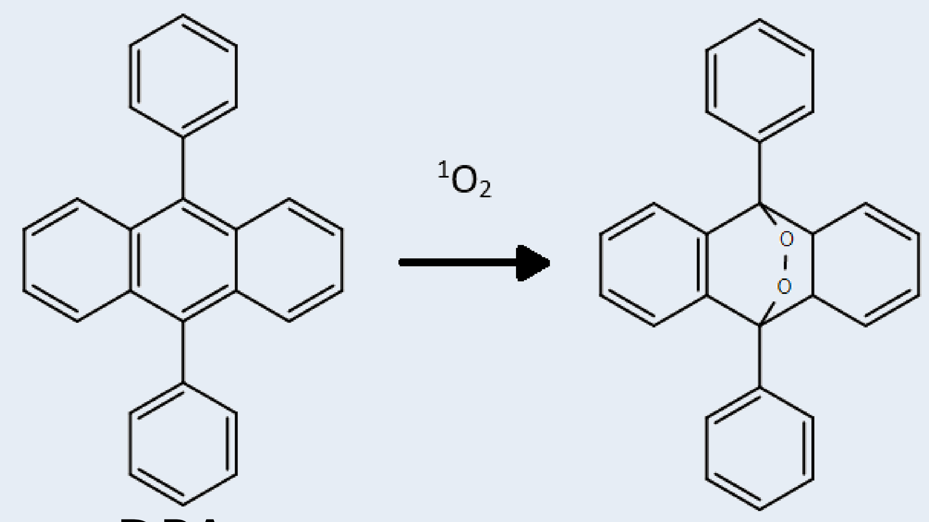
Table 2: Dimensions of monolithic reactors

Monolith	$d_{channel}$ (mm)	Dimensions	L(mm)	Leds used
1	1	16x2	150	18
2	1	32x2	150	36
3	2	16x2	150	18
4	1	16x4	150	18



Model reaction

The model reaction used in this study was the photocatalytic oxidation of DPA with oxygen using the photosensitizer Rose Bengal forming the endoperoxide of DPA. It was performed in acetonitrile with a concentration of 0,5 mM of DPA.



DPA

Figure 1: Photocatalytic oxidation of DPA to the endoperoxide of DPA

Results & discussion

The results at optimal working conditions, near 80% conversion are shown in Figure 2. Monolith 2 shows the highest STY and PSTY out of the tested monoliths. This is mostly due to the larger volume of the reactor, wasting less energy from light and monolith 2 also receives double the amount of light due to its larger surface compared to the other monoliths. Comparing monolith 2 to the batch reactor the batch reactor is 6.6 times more energy efficient but 26 times less productive. Compared to the FFPM with 8 parallel channels [3], monolith 2 is 20 times more productive and 13 times more energy efficient. Compared to the LSC-PM monolith 2 has a STY 6,3 times larger,

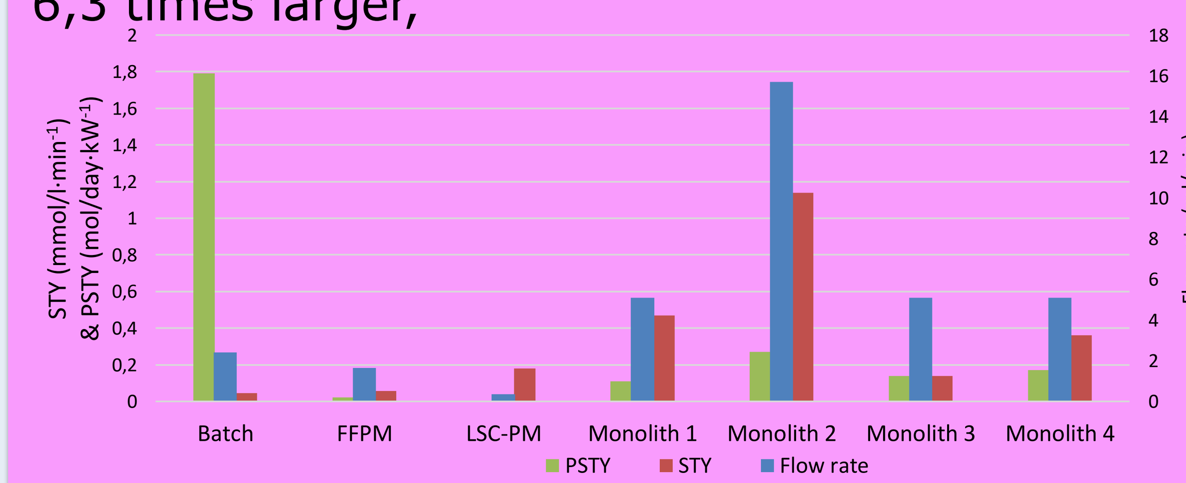


Figure 2: Comparison between different photoreactors based on STY, PSTY and volume per time unit at conversions near 80%

At last, the first steps towards slug flow in the translucent monolithic reactor were achieved but could not yet be characterized and optimized.

Conclusion

When comparing the translucent monolithic reactor to other photochemical reactors, it can be concluded that the translucent monolithic reactor is more productive than the FFPM, LSC-PM and the batch reactor even though the batch reactor has proven to be more energy efficient. Therefore, the translucent monolithic reactor is a promising design for industrialization of photochemical reactors. At last, the first steps towards slug flow were made. A stable slug flow within the monolithic reactor was achieved but was not yet characterized. The introduction of slug flow could greatly increase the performance of the monolithic reactor due to the expected increase of mass transfer. Furthermore, it would be interesting to finalize the characterization and optimization of slug flow within the monolithic reactor and determine the influence on the performance.

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