# Development and Application of a Novel MEMS-based Microreactor System for Gas-Phase Catalytic Reactions

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## Introduction

Miniaturization of electro-mechanical systems, analytical instrumentation, fluid transport hardware, process sensors, and other technological devices over the past decade has been a key driver in the development of Microreaction Technology (MRT) [1]. Advances in MRT for catalytic reacting systems have been presented annually since 1997 at the International Conference on Microreaction Technology (IMRET) with the latest one being IMRET-10 [2]. The advantages of MRT and reactor system miniaturization versus conventional reactor systems include smaller system footprint, lower process hazards, reduced reagent consumption, lower rates of waste generation, higher heat and mass transport rates, and improved process control [3]. Nevertheless, achieving these advantages also leads to new engineering challenges, such as fabrication of precision miniature components and process sensors, creation of robust component packaging and device integration schemes, defining methods for incorporating catalysts, and creating new instrument control schemes.

A new miniaturized system for studying gas-phase heterogeneous reactions under steady-state or dynamic conditions will be described that represents a notable departure from existing approaches for MRT systems. All key system functions, such as control of reactant flows, temperatures, process control, and gas-phase catalyzed reaction are performed on an array of custom-designed circuit boards that ft inside a standard Compaq PCI computer chassis. The catalytic oxidation of methane and ammonia are performed over a Pt film in separate investigations to demonstrate the viability of the experimental approach and modeling.

## Materials and Methods

Figure 1a shows a photograph of the Compaq PCI computer chassis which contains two reactor circuit boards along with various supporting boards for control of various temperatures, reactant gas flow rates, and safety monitoring. Each reactor board contains two parallel reactor channels on a single multi-laminate silicon chip die. The latter can be easily installed or removed using a modified industry-standard DieMate™ socket that is normally used for parallel testing of integrated circuits. The microreactor socket that is mounted on the reactor boards is shown in Figure 1b. Each rectangular reaction channel has dimensions of 50 μm x 50 μm x 500 μm and contains seven Pt metal heaters and temperature sensors. Each reaction channel etched on the chip resembles a "Y" where each top leg is supplied by two independently-controlled separate feed gas streams with on-board mixing. The catalyst is deposited as a thin film on the underside of a SiN film that forms the top layer of the reactor.

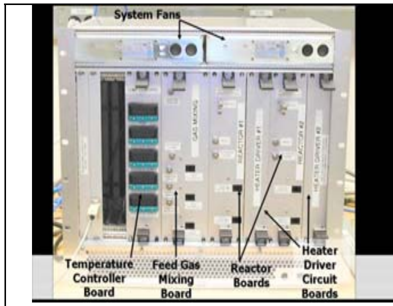


Fig 1a. Computer chassis showing various circuit boards for process functions.

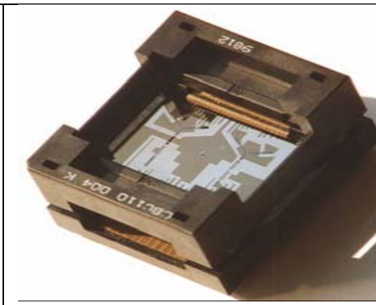

Fig 1b. Silicon chip-based microreactor with dual channels.

## Results and Discussion

Results from the oxidation of $NH_3$ over Pt from one of the four microreactor channels are shown in Figure 2. The selectivity data indicates that significant amounts of NO are produced during the oxidation of $NH_3$ since it approaches ca. 30% from 250 to 500ºC. Small amounts of $N_2O$ are detected starting at approximately 400ºC. Detailed 2-D and 3-D models of the microreactor that account for transport-kinetic interactions have been developed and provide accurate predictions of the measured performance data.

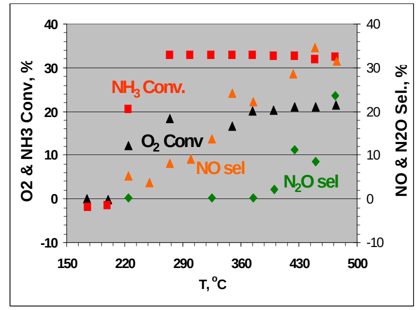


Fig 2. $NH_3$ oxidation performance data.

## Significance

The microreactor design represents a notable departure from existing approaches for studying catalyzed systems since it uses standard computer boards as the platform with MEMS components with improved safety and process control compared to conventional methods.

## References

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3. Mills, P. L., Quiram, D. J. and Ryley, J. F., Microreactor technology and process miniaturization for catalytic reactions—A perspective on recent developments and emerging technologies, *Chem. Engng. Sc*i. 62(24), *December 2007*, *Pages 6992-7010*.