MIT–MicroChemical Systems Technology Center

Personnel

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Sponsorship

Air Products and Chemicals, Asahi Glass Company, Asahi Kasei Corporation, Boehringer Ingelheim Pharmaceuticals, Daikin Industries, DuPont Company, Mitsubishi Chemical Corporation, Pfizer, Syngenta

This is a multidisciplinary Center focused on design and fabrication of new integrated microchemical systems for discovery, synthesis, and development of chemicals and processes relevant to chemical and pharmaceutical industries. Microfabrication techniques and scale-up by replication have fueled spectacular advances in the electronics industry, rapidly revolutionizing biological research and drug discovery. Microfabrication offers a similar potential for faster, cheaper, better chemical product research and development. Microchemical systems combined with instrumentation in small bench top units would clearly require less fume hood space, utilities, produce less waste, and offer safety advantages. Moreover, they would greatly enhance research and development productivity through high-throughput screening of catalysts and process chemistries, as well as efficient data integration.

Microreaction technology has several potential advantages for chemical production. The high heat and mass transfer rates possible in microfluidic systems allow reactions to be performed under more aggressive conditions with higher yields than can be achieved with conventional reactors. More importantly, new reaction pathways deemed too difficult in conventional macroscopic equipment would be pursued. The inherent safety characteristics of the technology suggest that production scale systems of multiple microreactors should enable distributed point-of-use synthesis of chemicals with storage and shipping limitations, such as highly reactive and toxic intermediates. Scale-up to production levels by replication of microreactor units used in the laboratory would eliminate costly redesign and pilot plant experiments, thereby shortening the development time from laboratory to commercial production. The

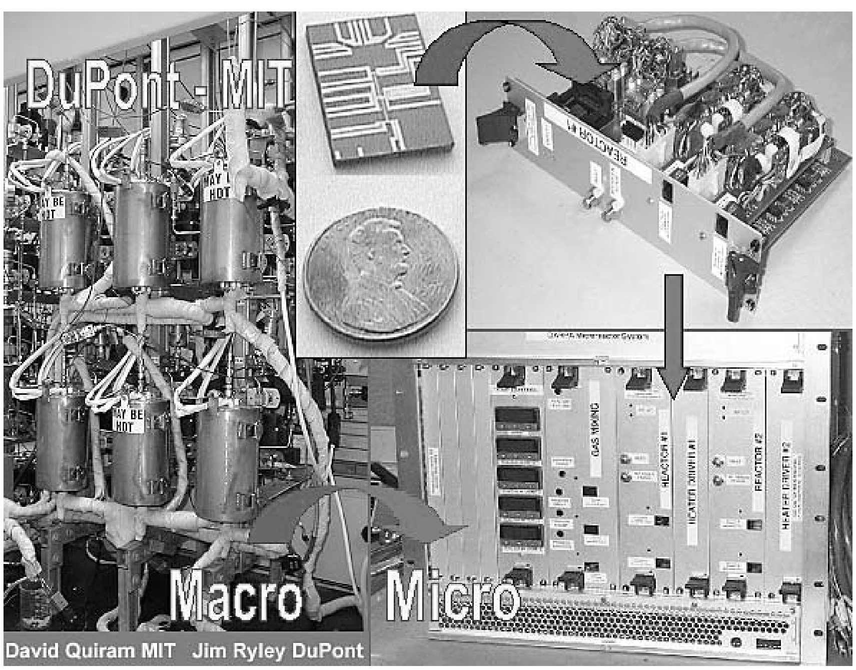

Fig. 1: Integrated microchemical system developed in collaboration with DuPont.

approach would be particularly advantageous for the fine chemical and pharmaceutical industries, where production amounts are often small. The strategy would also allow for scheduled, gradual investment in new chemical production facilities without committing to a large production facility from the outset, thus reducing risks and high capital costs.

In developing microreaction technology, it will be essential to focus on systems where microfabrication can provide unique process advantages. Such advantages could be derived from increased mass and heat transfer, leading to improved yield and safety for an existing process. The real value of the miniaturization effort, however, would be in exploring new reaction pathways and finding economical and environmentally benign solutions to chemical manufacturing. It will be important to exploit characteristics resulting from the small dimensions beyond the high transport rates, specifically forces associated with high surface area-to-volume ratios. In order for microreactors to move beyond the laboratory into chemical production, they must also be integrated with sensors and actuators, either on the same chip, or through hybrid integration schemes. The integration of chemical systems with sensors in µTAS is already rapidly expanding the field, and cross-fertilization with microreactors for chemical synthesis will ultimately result in integrated chemical

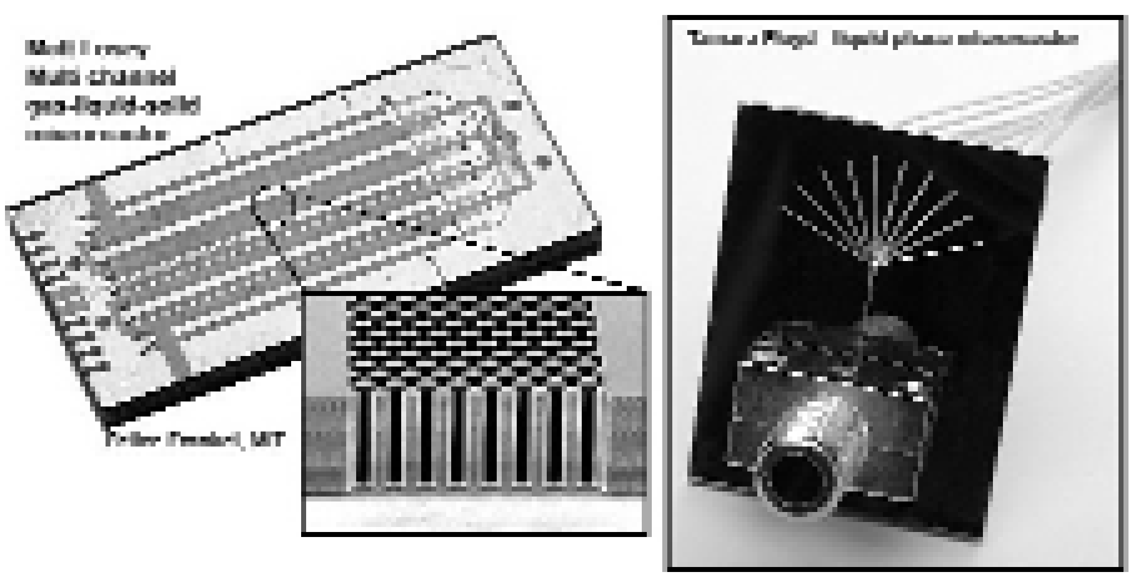

Fig. 2: Examples of microreactors. Left: multiphase system with microfabricated catalyst support. Right – liquid phase mixer with integrated optics

processors. The packaging of multiple reactors presents significant challenges in fluid handling, local reactor monitoring, and control.

Research in the Center addresses the above issues through innovations in microreactor technology and applications. A partial list of focus areas includes:

- Evaluation of the value of the microreaction technology to the chemical and pharmaceutical industry by testing many different chemical systems in microreactors, emphasizing those chemical systems that would be difficult or impossible to do at larger scales, i.e. less controlled conditions.

- Operation of integrated systems (for single and multistage synthesis).

- Reaction engineering design strategies (including economic considerations) and tools for microchemical systems.

- Versatile microreactor designs integrating fluid, electrical, and optical distribution systems that are applicable to a broad range of chemical systems.

- Microreactor packaging strategies allowing easy interchange of reaction units and integration with microfluidics and control systems.

- Microfabrication methods with a broad range of materials (polymers, metals, and ceramics) compatible with chemical processes and establish criteria for materials selection.

- Microscale separation techniques that are analogs or replacements of distillation, extraction, and chromatographic techniques used in conventional laboratory synthesis.