2-7-3. Material Production Using Microchannels

Overview

Material production using flow photoreactions, which use microchannels as photoreaction environment, has been developed (Fig. 1). Compared to conventional batch photoreactions, flow photoreactions offer advantages such as efficient photoirradiation, suppression of side reactions, and precise control of reaction time and temperature. Photoreactions can be carried out efficiently in a homogeneous media (solution) as well as immiscible phases (gas–liquid and solid–liquid). Furthermore, the use of microchannels enables to safely use toxic gases and explosive substances in photoreactions.

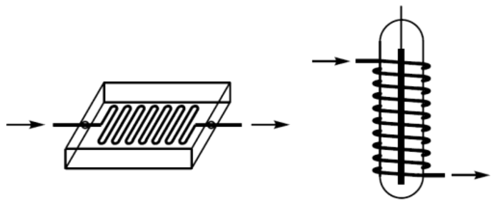

Figure 1. Flow photoreaction.

Current Status and Frontiers

Flow photoreactions using microchannels have advantages over conventional batch photoreactions, such as efficient photoirradiation, precise control of reaction time and temperature, suppression of side reactions, and efficient heterogeneous photoreactions.[1-3] Over the past 20 years since the middle of 2000s, organic synthetic chemists have been readily accessible to the flow photoreactions because inexpensive fluoropolymer tubes and UV–visible LEDs were widely used as simple flow reactors and light sources, respectively, in conjunction with the advances in 3D printing technology. Under these circumstances, many synthetically useful photosensitized reactions have been developed and employed for flow photoreactions (Fig. 2). Below, we describe some representative examples of flow photoreactions using microchannels.

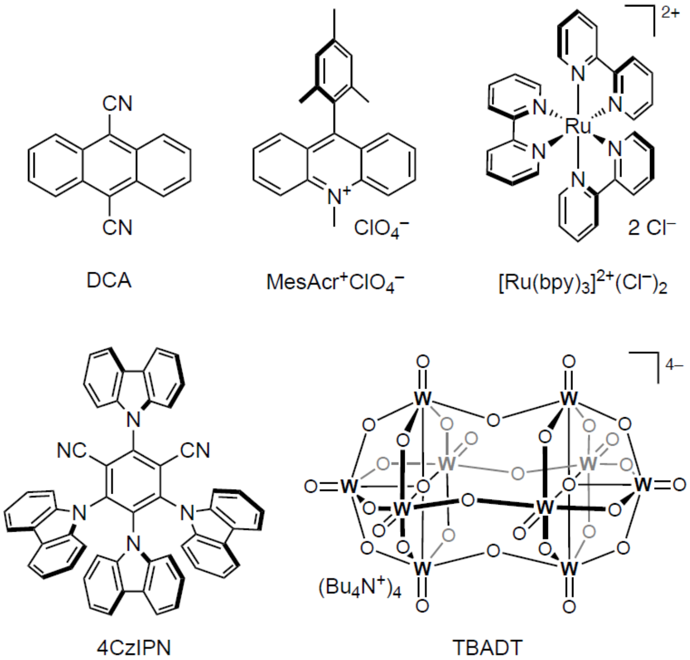

Figure 2. Photosensitizers used in the flow photoreactions.

1. Homogeneous flow photoreactions

Photosubstitution of aryl halides, selective C(sp^3)–H functionalization, and benzylic photohalogenation of aromatic compounds have been reported. Flow photoreactions are also useful methods for developing functional materials[4] and drugs discovery.

2. Flow photoreactions in the gas–liquid phases

Photoreactions using immiscible substrate solution and reactant gas mixed in the flow reactor can enlarge the gas–liquid contacting area compared with that in the batch reactor, thereby improving reaction efficiency. This method has been used for photooxygenation and [2+2] photocycloaddition reactions. Furthermore, photochemical chlorination and trifluoromethylation reactions using hazardous gases (Cl_2 and CF_3I), which are difficult to handle in a large-scale batch reaction, have been reported.

3. Flow photoreactions in the solid–liquid phases

Photochemical water purification using TiO_2-immobilized flow reactor has been reported.

In addition to the above, rapid optimization of reaction conditions using inline analyses (HPLC, UV–Vis, IR, and NMR *etc.*) and automation using robotic arms have been attempted in the flow photoreactions. High-throughput organic synthesis is being achieved by combining digitalization and automation in the material production using flow photoreactions.

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Future Perspectives and Directions

Challenges to be resolved or realized within 5 years: Development and widespread use of low-cost flow photoreaction systems, Mass production of materials at an industrial scale using flow photoreaction

Challenges to be resolved or realized within 10 years: Automation of flow photoreactions, AI-assisted optimization of flow photoreaction conditions

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