Plasmonic Photocatalytic Oxidization of NH_4^+ in Micro Optical Fluidic Chip

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This paper reports a new design of micro optofluidic chips in the application of plasmonic photocatalytic oxidization of Ammonium ions (NH_4^+) dissolved in water under light illumination, Fig. 1. In this report, the Au nanoparticles (NPs) replaced the typically used catalyst in typical artificial nitrogen cycle. The micro optical fluidic chip (MOFC) reactor is good with high mass transfer rate that can enhance processing efficiency of chemical reaction [1]. The UV light transmittable construction material, e.g. glass, Polydimethylsiloxane (PDMS), or NOA81 [1], makes the MOFC perfectly suitable for photocatalytic reaction.

Typically, artificial nitrogen cycle processes via the wet air oxidization (WAO) method oxidize and eliminate the dissolved NH_4^+ from water with temperature higher than 150 °C and high pressure. The plasmonic heating in metal nanostructures and localized high temperature under light illumination enhances chemical reactions [2-5]. In this study, the pre-deposited layer of (3-Aminopropyl)trimethoxysilane (APTMS) fixed various sized Au NPs on the inner walls of the flow channel, Fig. 2. The pink color in the lower chip is coming from the scattering light of the fixed Au nanoparticles with size of 20 nm. Only the area of the rectangle fluidic channel, 2 cm (W) × 3 cm (L) × 58 µm (H), deposited with APTMS layer can catch Au NPs, see SEM data in Fig. 3. No obvious depletion observed after the experiments of NH_4^+ oxidization under alkaline conditions.

The MOFC reactor with or without fixed 20 nm Au nanoparticles presented oxidization of NH_4^+ ions dissolved in water under light illumination, Fig. 1. Two array of profusion channels with 10 µm in width separated and limited the water flow-in speed from input-reservoir. External visible light supplied by halogen lamps illuminated the channel and induce surface plasmon resonances on Au nanoparticles. Two groups of experiments with various flow speed of test solution processed under alkaline condition with adding sodium hydroxide (NaOH). The pH adjustment increased the initial pH value to about 11.5 and supplied hydroxide ions (OH^-) for oxidization of NH_4^+ ions in water.

The reserved NH_4^+ ions in test solution after experiments with various water pumping flow speed was measured and depicted in Fig. 4. The experiments with fixed Au NPs had concentration of reserved NH_4^+ smaller than that with no Au NPs after 1 hr of processing time. The Au nanoparticles presented plasmonic enhancement of the chemical catalytic oxidization of NH_4^+ ions in water in the MOFC reactor.

In conclusion, the plasmonic oxidation of NH_4^+ ions in water presented inside the MOFC reactor with Au NPs as photocatalyst. The MOFC reactor shows great potential for further investigation in the future.

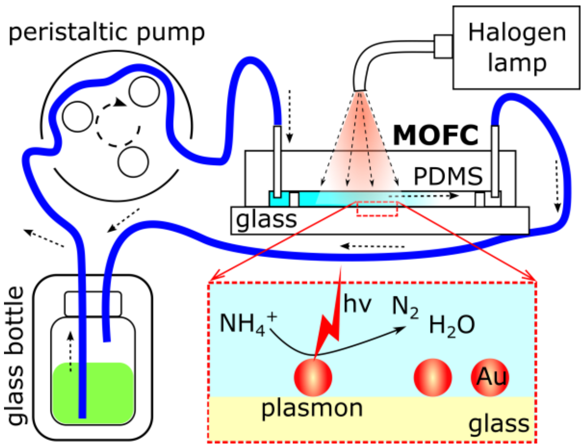

Fig. 1. Schematics of the MOFC reactor.

Fig. 2. MOFC reactor with and without fixed Au NPs.

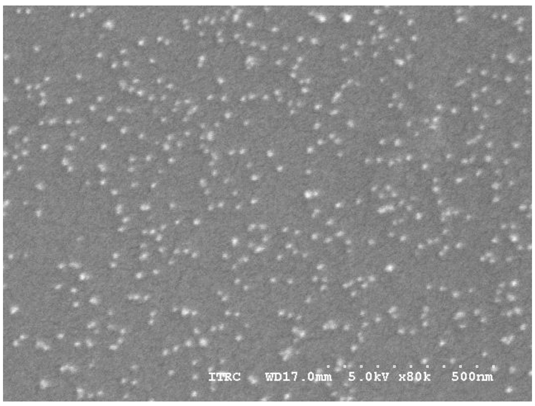

Fig. 3. Au NPs fixed on glass substrate.

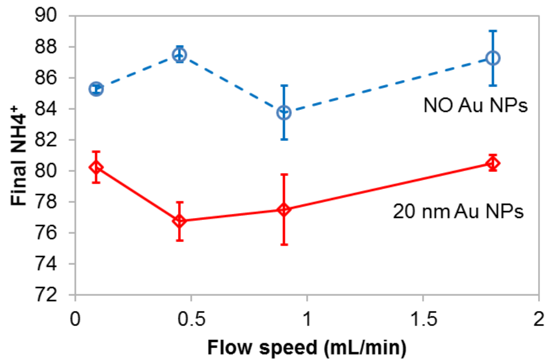

Fig. 4. Reserved NH_4^+ after treatment for various water pumping flow speed with and without Au NPs fixed in MOFC reactor.

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