Gold Nanoparticle Synthesis using High-speed Pulsed Mixing Microfluidic Device

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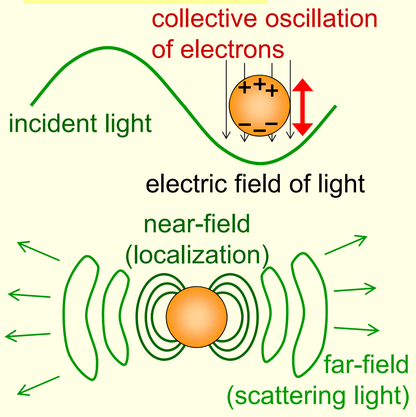
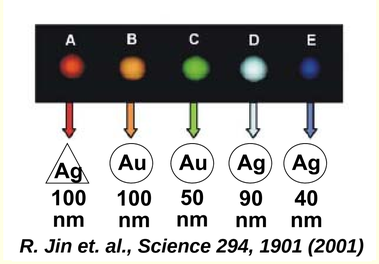
Abstract **:** For chemical syntheses in a microreactor, mixing speed is thought to be significant parameter in the case that chemical reaction speed is significant high. For gold nanoparticle synthesis process, an initial reaction has been known as a rapid reaction. Therefore, so far we have developed a microreactor for gold nanoparticle synthesis using a pulsed mixing microfluidic device with T-shaped mixing channels for high-speed mixing. In this study, we uses the novel pulsed mixing method with cross-shaped mixing channels in a microreactor to improve the mixing speed. The mixing achieved higher mixing speed than the conventional method. This study found that mixing speed of two solutions was an effective parameter for increasing particle size uniformity and that higher mixing speed achieved higher particle size uniformity.

Gold nanoparticle

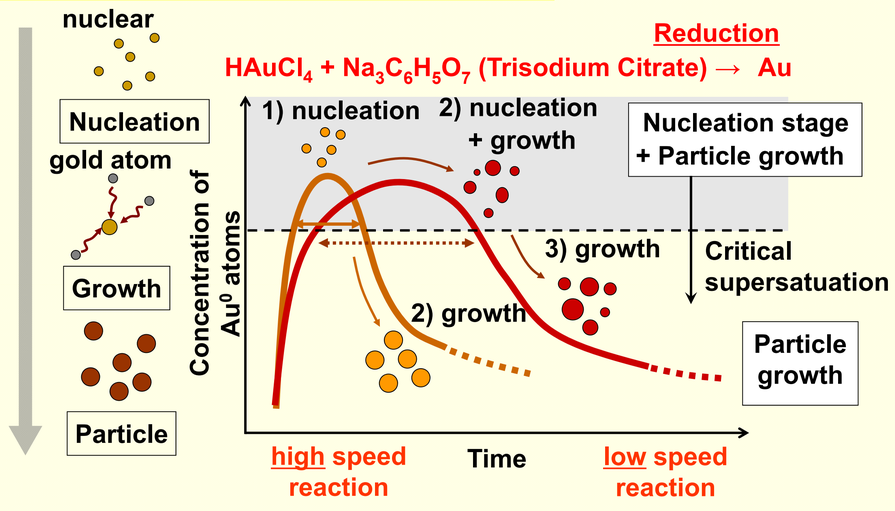
Plasmonic resonance





R. Jin et. al., Science 294, 1901 (2001)

Particle synthesis mechanism



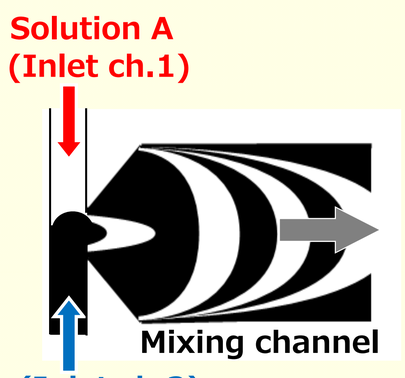
Particle size and **size distribution** strongly depend on **"nucleation period"**.

→ **"Nucleation period"** can be controlled by **"mixing speed"**.

"Uniformly sized particle" can be synthesized by **"high speed mixing"**.

Microfluidic pulse mixing method

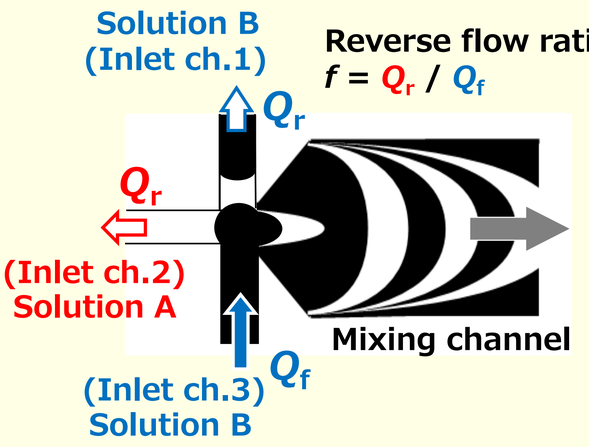
(a) Conventional T-shaped channel with two inlets



Pumping order:

(ch.1) → (ch.2) →
(ch.1) → (ch.2) →

(b) Proposed cross-shaped channel with three inlets controlling reverse flows

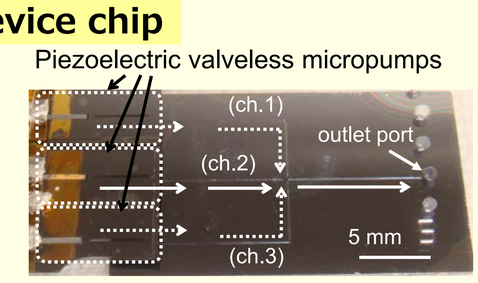


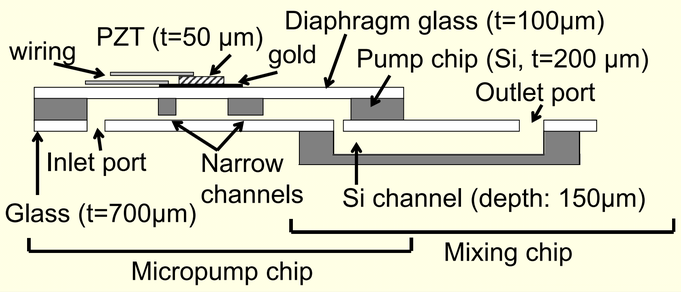
Pumping order (forward flow):

(ch.1)→(ch.2)→(ch.3)→(ch.2)→

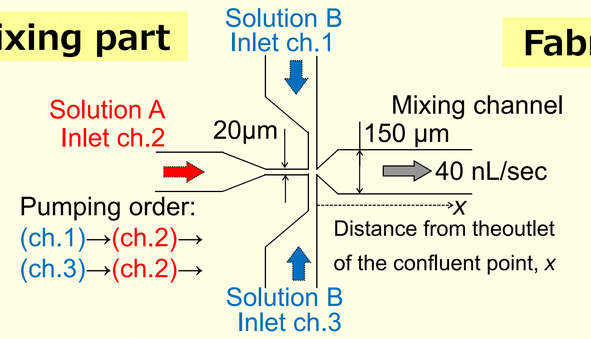
Microfluidic device

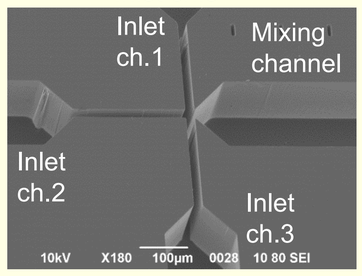
Device chip



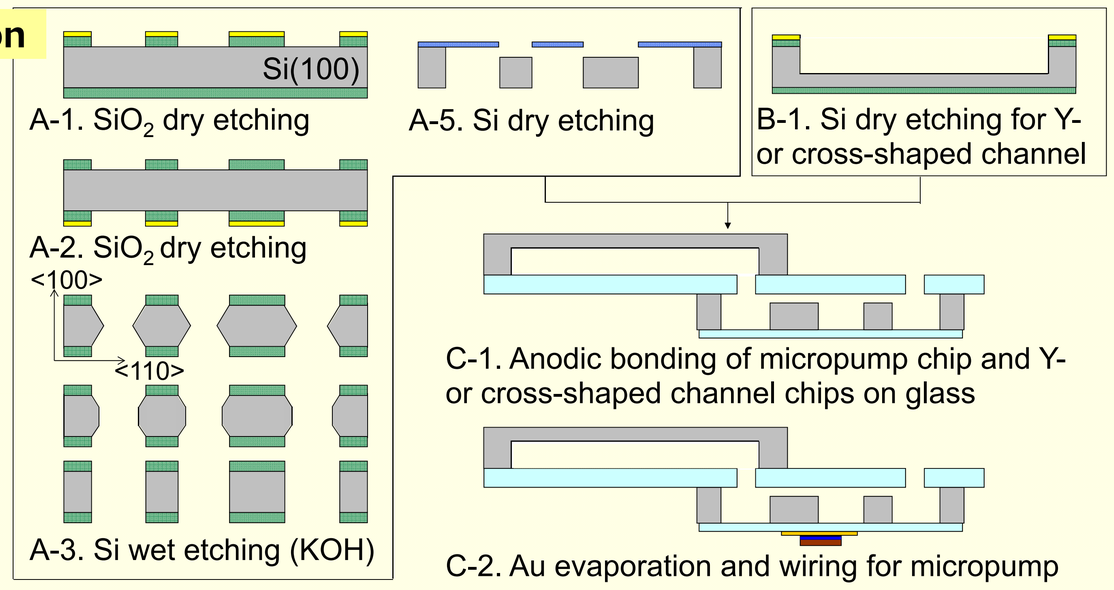


Mixing part



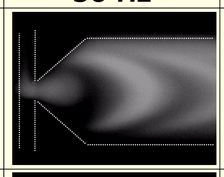
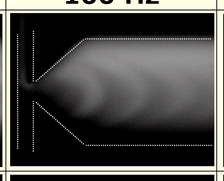
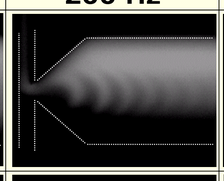
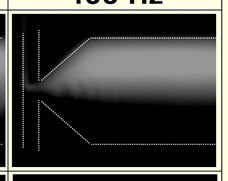
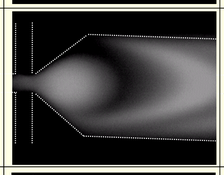
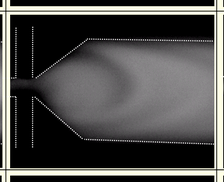
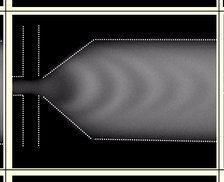
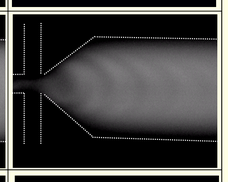
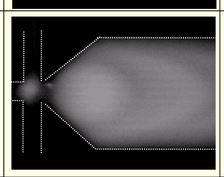
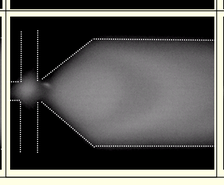
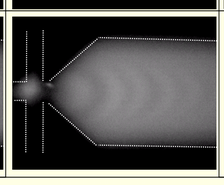
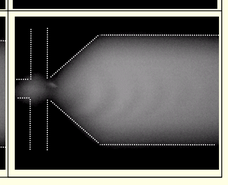


Fabrication

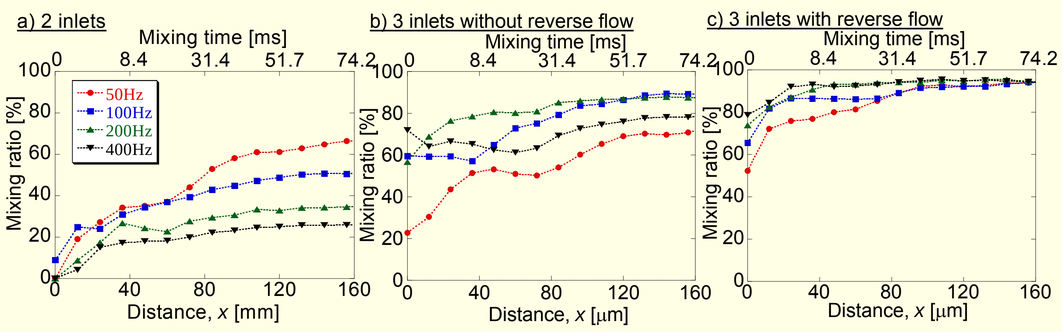


Mixing performance

Fluorescence images

	Switching frequency of two-solution pumping			
	50 Hz	100 Hz	200 Hz	400 Hz
(a) 2 inlets				
(b) 3 inlets without reverse flow				
(c) 3 inlets with reverse flow				

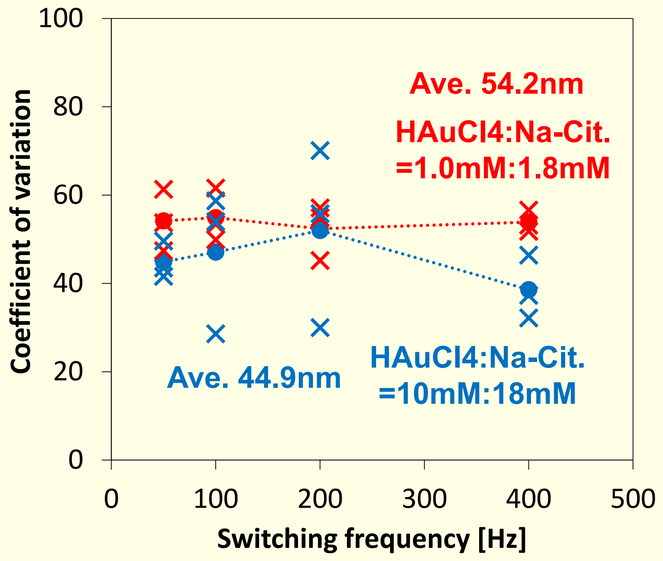
Fluorescence images



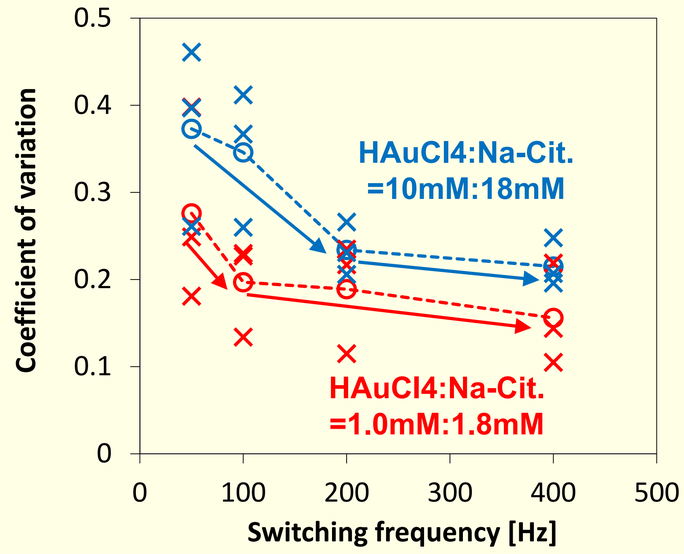
- High mixing speed and its control were achieved using the proposed method.

Experimental results of particle synthesis

Mean particle diameter



Coefficient of variation of particle size



- In the both cases of concentrations, we observed that the coefficient of variation of the particle diameter tended to decrease with increasing the switching frequency.
- At the $HAuCl_4$ concentrations of 1.0 mM and 10 mM, the coefficients of variation show saturation tendencies from 100 Hz and 200 Hz, respectively.
- This is because higher concentration of solutions provides higher reaction speed. At higher reaction speed, mixing speed has an effect of synthesis up to higher switching frequency.
- From these results we confirmed that the proposed method for high mixing speed is useful for uniformly sized nanoparticle synthesis.