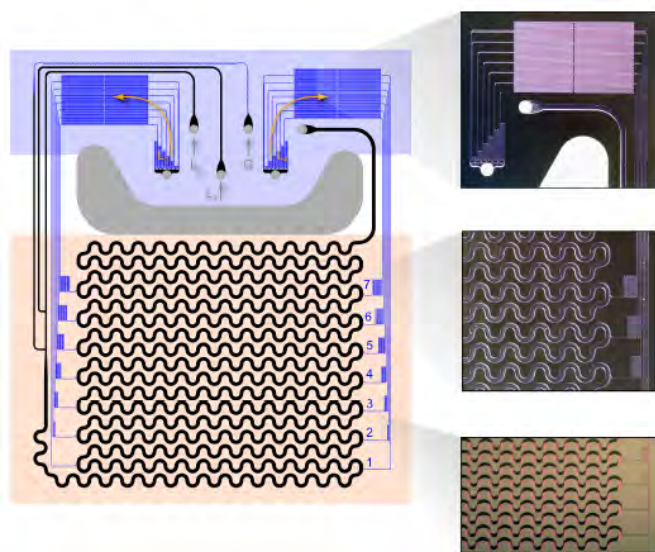


# Microreactors for Synthesis of Quantum Dots

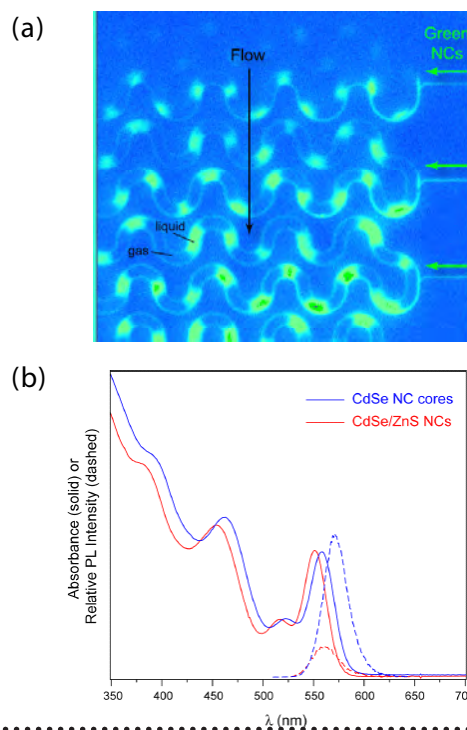
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We have fabricated gas-liquid, segmented-flow reactors with multiple temperature zones for the synthesis and the overcoating of quantum dots (QDs). In contrast to single-phase flow reactors, the segmented flow approach enables rapid mixing and narrow residence time distribution, factors which strongly influence the ultimate QD size distribution. The silicon-glass reactors accommodate a 1-m-long reaction channel (hydraulic diameter  $\approx 400 \mu\text{m}$ ) and swallow side channels for multiple additional injections of precursors inside the main channel (Figure 1). Pressure-drop channels were added in order to avoid backflow into the side channels. Two temperature zones are maintained, a heated region ( $> 260 \text{ }^\circ\text{C}$ ) and a cooled quenching region ( $< 70 \text{ }^\circ\text{C}$ ). Measurements of the flow distribution (Figure 2a) show that this side manifold design results in very uniform distribution even at very low nominal flow rates. As a model system, monodispersed CdSe and CdSe/ZnS QDs were prepared using this reactor. For the preparation of

CdSe QDs, cadmium and selenium precursor solutions were delivered separately in the cooled region and were thereafter mixed in the heated region. An inert gas stream is introduced further downstream to form a segmented gas-liquid flow, thereby rapidly mixing the precursors and initiating the reaction, as was shown in a previous work [1]. In the case of the synthesis of CdSe/ZnS QDs, CdSe cores are introduced directly inside the main channel, while Zn and S precursors are added through the side swallow channels, allowing the overcoating. The reaction is stopped when the fluids enter the cooled outlet region of the device. When we vary the process parameters (temperature, precursors flow rates), the size of the cores material can be tuned without sacrificing the monodispersity. In addition, the overcoating of CdSe cores allows shifting the absorbance spectrum (5 nm), due to the presence of the ZnS layering (Figure 2b).



▲ Figure 1: Microreactor design with two feeder channels (blue) for adding precursor into the main stream. Each channel has a length of 14 cm and a hydraulic diameter of  $50 \mu\text{m}$ , whereas the main reaction channel (black) is 1 m long and has a hydraulic diameter of  $400 \mu\text{m}$ .



▲ Figure 2: (a) False-color fluorescence image used for measuring the flow distribution. Green-emitting nanocrystals are continuously injected from the side channels from the right into a gas-ethanol segmented flow in the main channel. (b) Absorbance and photoluminescence spectra of CdSe cores and CdSe/ZnS core/shell nanocrystals in hexane.

## REFERENCES

- [1] B.K.H. Yen, A. Günther, M.A. Schmidt, K.F.Jensen, and M.G.Bawendi, "A microfabricated gas-liquid flow reactor for high-temperature synthesis: The case of CdSe quantum dots," *Angewandte Chemie International Edition*, vol. 44, no. 34, pp. 5447-5451, Aug. 2005.