

MIXING OF SMALL VOLUMES OF LIQUIDS BY CONVECTIVE FORCES INDUCED BY LOCALIZED HEATING

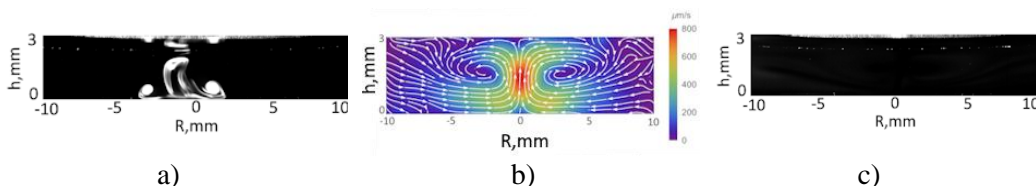
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Different modern technologies require mixing various liquids for numerous purposes. Depending on the application, different methods may be used (e.g., ultrasonic mixing, junction-channel mixing) [1]. Selecting an optimal approach can be complicated because many methods are inefficient for small liquid volumes (such as laboratory samples). In addition, some tasks require low-invasive approaches, which rules out several commonly used methods. Certain microbiological applications and the synthesis of new materials may also require temperature or pressure control; therefore, the development of new mixing methods remains of strong interest to the scientific community.

We propose a new approach based on convective hydrodynamic forces generated by local heating to mix small volumes of liquid. Fig. (a) shows the initial state of dye mixing in a flat water layer (0.8 mL). A high-concentration dye solution is introduced into pure water and then mixed until a quasi-uniform state is achieved.



(a) liquid layer immediately after addition of a high-concentration dye solution, (b) convective flow pattern, (c) final (quasi-uniform) state of the mixture

Local heating of the bottom substrate leads to the formation of a three-dimensional convective flow (Fig. (b)), which redistributes the dye throughout the liquid volume. Different liquids and additives require different times to reach equilibrium composition and produce different levels of mixing uniformity. A representative quasi-uniform final state is shown in Fig. (c). The developed method enables visual monitoring of dye concentration distribution and determination of the required mixing time. Precise thermal control using a Peltier element keeps the liquid temperature within a desired range, preserving temperature-sensitive chemicals. Local heating introduced by a focused laser beam or a miniature contact heater provides a means to initiate high-performance convection (up to 1–2 mm/s). Typical mixing times are 3–15 min, achieving steady-state uniformity of up to 80%.

1. Hessel V., Löwe H., Schönfeld F. Micromixers—a review on passive and active mixing principles // *Chemical Engineering Science*. 2005. Vol. 60, Nr 8–9. P. 2479–2501. <https://doi.org/10.1016/j.ces.2004.11.033>