# High Speed Microturbine Mixer for Kinetically Controlled Synthesis

## Supplementary Information

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**Video:**

*Microturbine Mixing:* Red and blue dyes are used to visualize mixing within the microturbine. This video begins with laminar flow through a stationary rotor. As flow rate increases, rotor spinning is initiated and two dyes are mixed. Video is recorded at 50 frames per second and played at 25 frames per second.

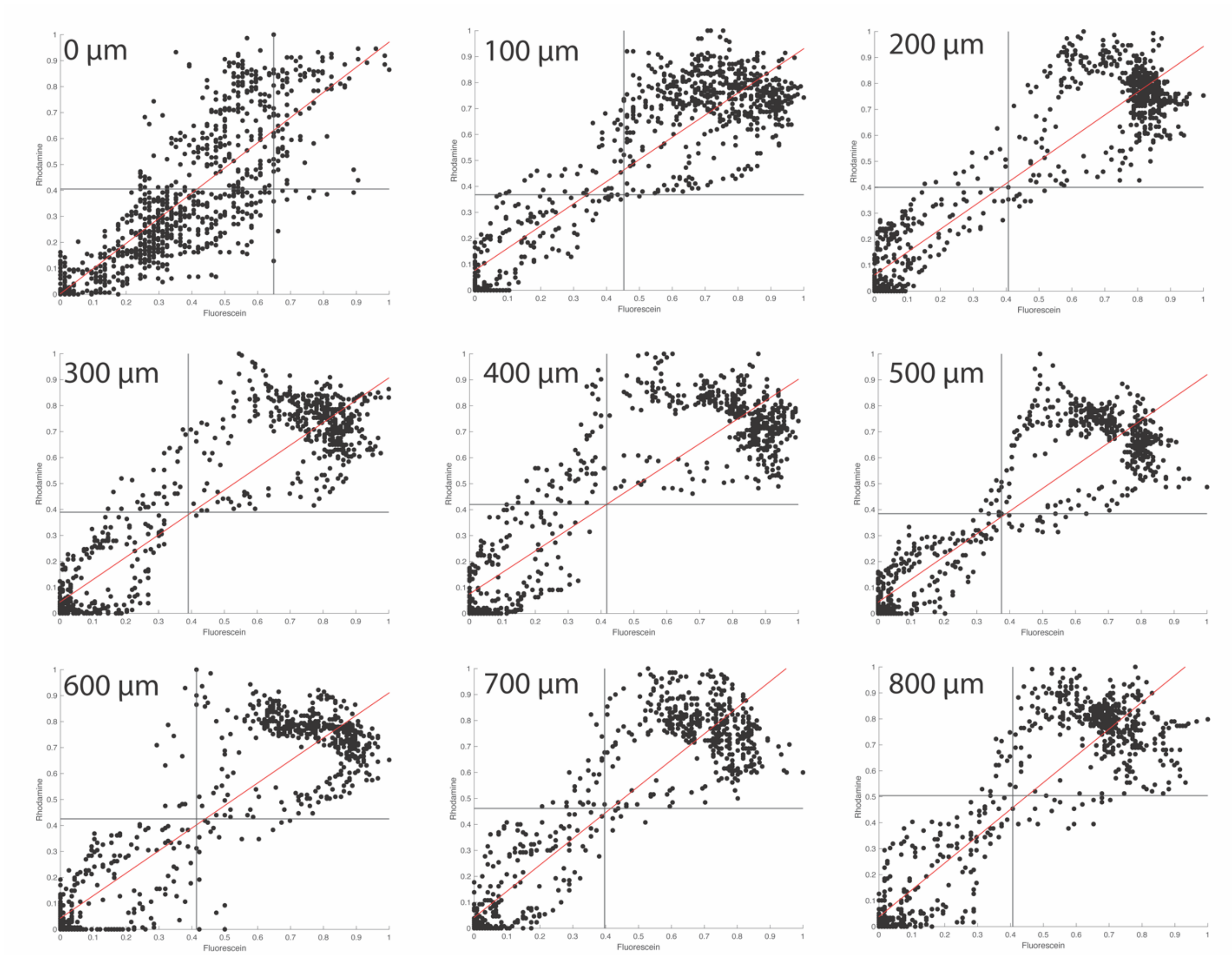
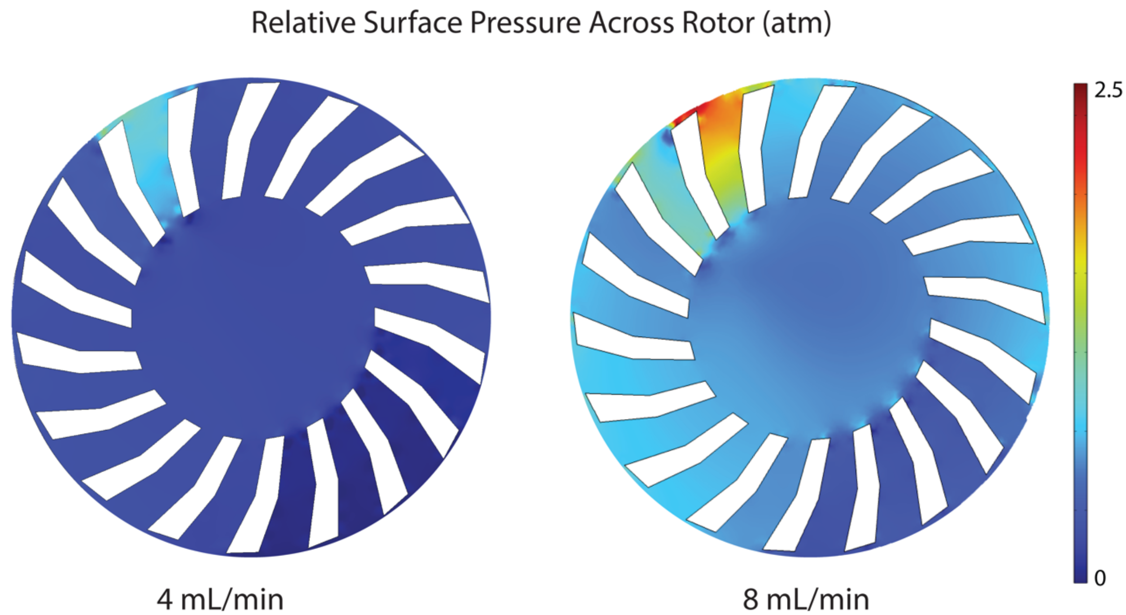
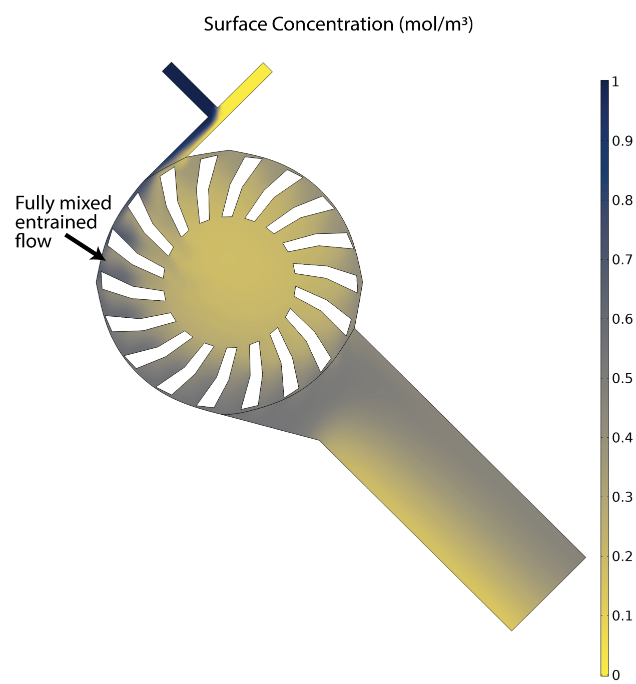


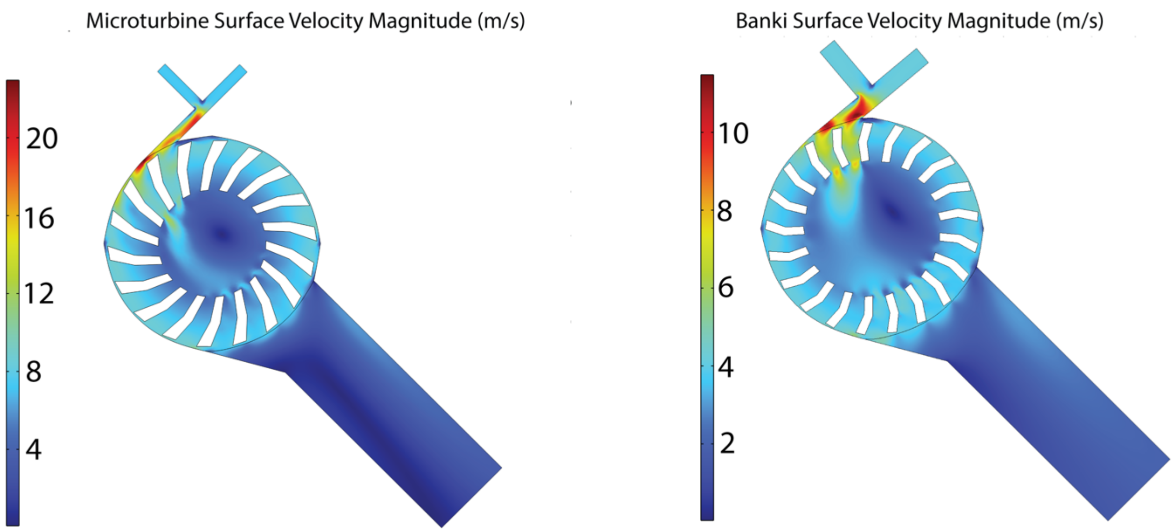

Figure S1: Cytofluorogram showing colocalization analysis of mixing profiles at steady state. The plots show the distribution of Rhodamine versus Fluorescein fluorescence intensities across the channel. By 200µm, the fluorophores are uniformly distributed, indicating homogeneous mixing. A distinct low recirculation region is observed between 300–400 µm, where the pixel values for Rhodamine are significantly higher, indicating a greater concentration in this area. The data suggest non-uniform mixing within this region, where a reduced flow velocity results in higher tracer retention. Beyond this point, the cytofluorogram demonstrates that the fluorophores once again become uniformly distributed across the channel.



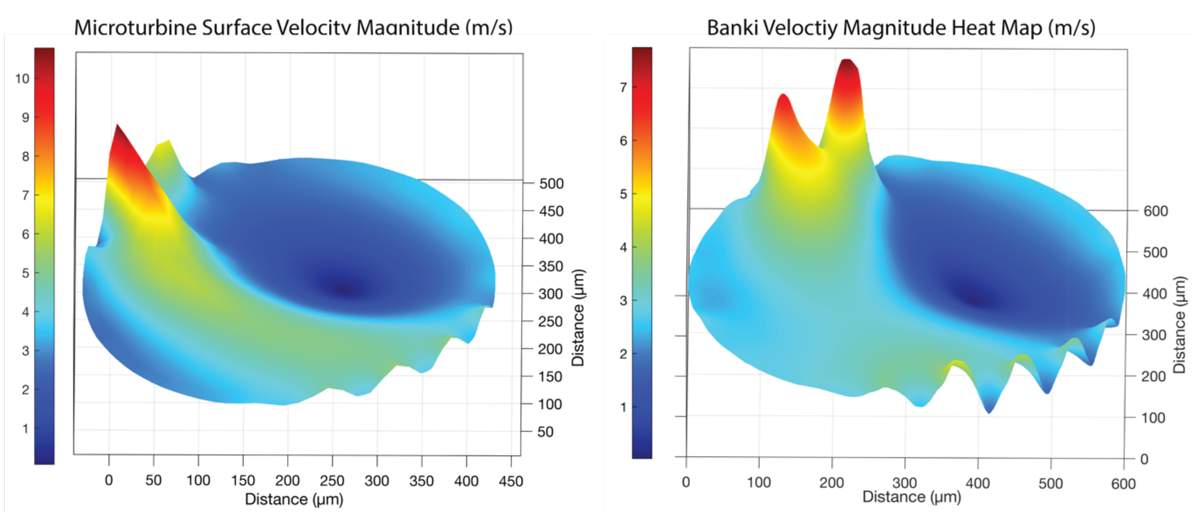

S2: COMSOL Multiphysics simulations of relative pressure inside the rotor at low and high flow rates. Cavitation arises due to high pressure drops. The plots reveal that at low flow rates, cavitation can occur at the second stage of the impeller (i.e. where the crossflow exits the rotor). However, at high flow rate, in addition to a very significant pressure drop at the second stage, a sufficiently high pressure drop also occurs at the blade tips in the first stage, substantially increasing the probability of cavitation at the point of energy transfer, reducing transfer efficiency.



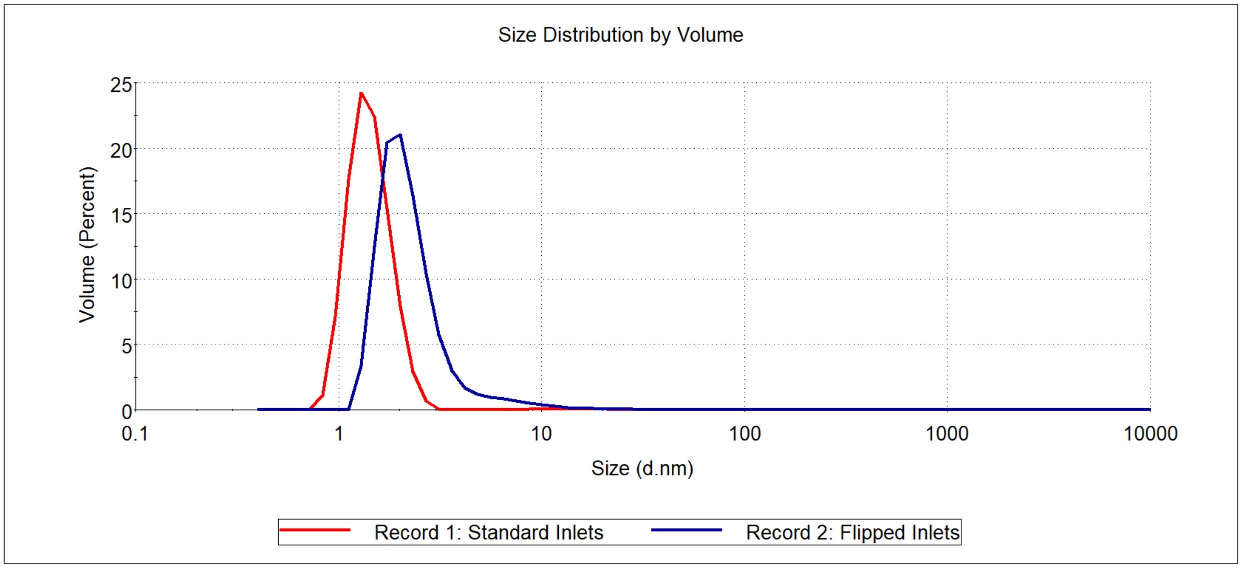

S3: To determine mixing time, the residence time for both the entrained and crossflow profiles were considered. The residence time for the entrained fluid is taken to be the time required to achieve one-half of a full rotor revolution. However, finite elemental analysis indicates that mixing efficiency reaches 90% within just 3/18 ths of a revolution. Indicating that for the optimized flow rate of 7 mL/min for ultra-small AgNP synthesis the fluid within the entrained region is homogeneously mixing in 196 µs. Thus, the crossflow contribution to mixing time is the limiting factor.



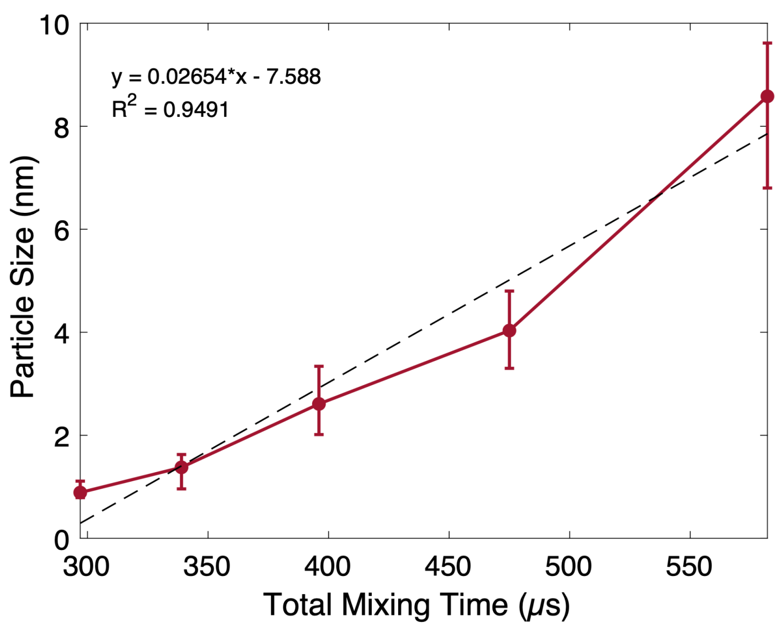

S4: Surface velocity magnitude for the (left) microturbine mixer and (right) a micromixer using Banki design parameters. The maximum surface velocities at a total flow rate of 7mL/min for microturbine and Banki mixers are 22 m/s and 11 m/s, respectively.




S5: The crossflow region for the microturbine mixer (left) and a micromixer using Banki design parameters (right) at a total flow rate of 7 mL/min. The crossflow residence time for the microturbine mixer (left), was calculated using simulated surface velocity profiles of the microturbine. The crossflow region was defined by areas with fluid velocities greater than 2 m/s. This volume was added to the volume between five blades—two from the first stage and three from the second—and divided by the flow rate to determine the crossflow residence time for the microturbine.




S6: DLS measurements for AgNPs synthesized at 7 mL/min. Standard inlets means that the AgNPs were synthesized with NaBH4 injected into inlet 1 and $AgNO_3$ injected into inlet 2. Flipped inlets means that the AgNPs were synthesized with $AgNO_3$ injected into inlet 1 and $NaBH_4$ injected into inlet 2. As shown, AgNP synthesis utilizing flipped inlets results in larger particle size and dispersion, which is likely due to the presence of unreacted Ag ions in the low flow velocity zone, leading to particle aggregation.




S7: Relationship between AgNP size and total mixing time in the microturbine. A linear fit yields a decent correlation coefficient of 0.95. A true linear fit is not anticipated, due to the fundamental thermodynamic stability of AgNPs at only specific sizes.