LabSmith Application Note

Zero Dead-Volume Mixing with uProcess and Hummingbird Nano Chips

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This application note describes how to set up a zero dead volume mixing process using LabSmith's uProcess syringe pumps, valves, reservoirs and software, and Hummingbird Nano "X" style or "Y" style helical mixer chips.

INTRODUCTION

The interaction of fluids in microfluidic systems is a challenging yet important application. These interactions can take the form of controlled reactions, distribution of particles (slurries), particle control in emulsions and control of concentration, among others. In many of these applications, the reagents can be very costly, so it is important to have a system that offers fast mixing, low swept volume and near zero dead volume.

A low volume mixing process can be readily created using Hummingbird Nano's passive, helical mixer chips and LabSmith's uProcess™ programmable microfluidic components. These inter-compatible components assemble easily for extremely low volume, automated flows.

EXPERIMENTAL SETUP

Figure 1 shows a LabSmith uProcess breadboard, syringe pumps, valves and reservoirs with the Hummingbird Nano "X" style mixer chip. The chip includes integrated 1/16" OD tubing that connects directly to the uProcess components for smooth transitional flow with no dead volume. Table 1 shows the components used for this application.

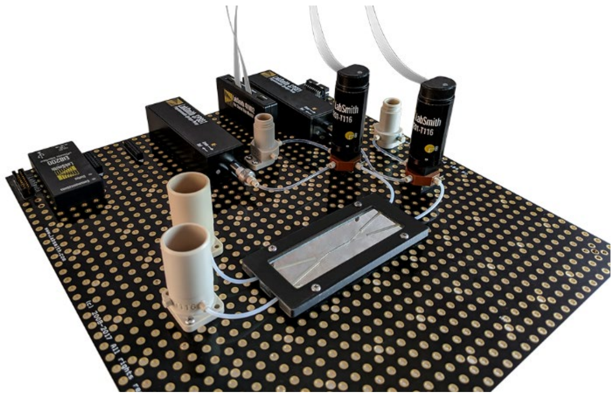

Fig. 1: uProcess setup with Hummingbird "X" style chip.

Hummingbird Nano offers two versions of mixing chips (Figure 2): the conventional "Y" style mixer with two inputs and a single output, and the novel "X" style mixer that allows two streams to be mixed and then split into separate streams for further processing. Both chip styles have smooth, circular channels that come together to form a double helix in the mixing region. The chips are cast as a single piece, eliminating bonding and its associated challenges.

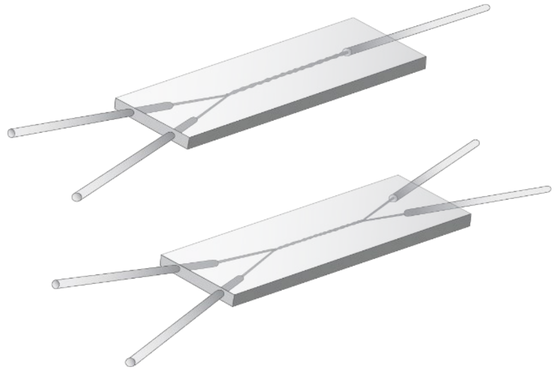

Fig 2: Hummingbird Nano "Y" and "X" style mixer chips.

The setup in Figure 1 includes two input fluid circuits. Each circuit employs a 3-port valve connected to a syringe pump, reagent reservoir, and the chip inlet. The valve connects the syringe to the reservoir to fill the syringe, then switches to connect the syringe to the chip inlet to dispense the reagent.

TABLE 1. Components in Setup		
LabSmith P/N	**Description**	**Qty**
iBB	uProcess Breadboard	1
EIB200	uProcess Automation Interface	1
4VM02	Valve Manifold	1
SPS01-080-T116	Syringe Pump	2
AV201-T116	uProcess Automated 3-Port Selector Valve	2
BBRES-1ML-T116	Breadboard Reservoir, 1 mL	2
BBRES-5ML-T116	Breadboard Reservoir, 5 mL	2
T116-101	CapTite Plug	14
T116-100	CapTite Fitting	8
TUBE116-030P	PEEK Capillary Tubing	1
MXX-280-16	Hummingbird "X"- Style Chip, 1/16" PTFE Connectors	1
iBB-TOOLS	Breadboard mounting hardware & tools	1

DIFFERENTIAL FLOWRATES

The concentration of each output stream of the "X" style chip is controlled by setting the input stream flowrates in the uProcess automation software. The forces in dilution and concentration or selective mixing will vary greatly depending on the viscosities and the specified flowrates. Therefore, the flowrates must be calibrated based on the properties of the input fluids.

Several methods are available to measure concentration. In this example, each effluent is collected in cuvettes, and percent volume concentration is measured using a colorimeter. Reagent A is 100% DI H_2O, and Reagent B is DI H_2O with 3.26% dye (by volume). As shown in Figure 3, the two syringe pumps load the reagents and then dispense at the desired flowrates.

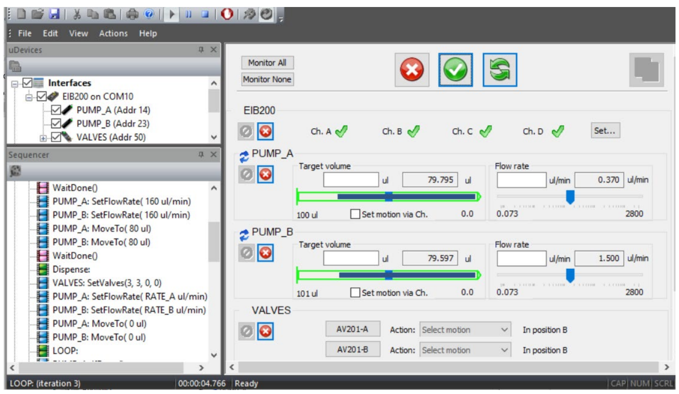

Fig. 3: uProcess software control panel.

Figure 4 shows a sample result for a Reynolds number of 83, with Reagent A flowing at 0.37 ml/min and Reagent B flowing at 1.5 mL/min. The mixing section of the "X" style chip has 5 helical stages. Mixing begins within the first helical stage.

TABLE 2. Mixing Zone Flow Rate = 1.87 ml/min; Re = 83				
Reagent	Initial Dye Concentration	Flowrate	Total Volume	Final Concentration
A	0.0 %	0.37 ml/min	1.3 ml	2.2 %
B	3.26 %	1.5 ml/min	5.2 ml	2.6 %

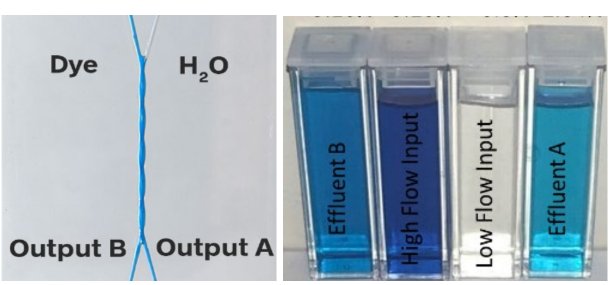

Fig. 4: (a) Sample "X" Style Mixing Chip; (b) concentrations of input and output streams.

Figure 5 shows the output concentrations versus Reynolds number. Note that as the Reynold's number increases the % concentration of the effluent streams converges to complete mixing of 3.02% (as confirmed using a "Y" style mixer). This occurs at Reynolds numbers above 700.

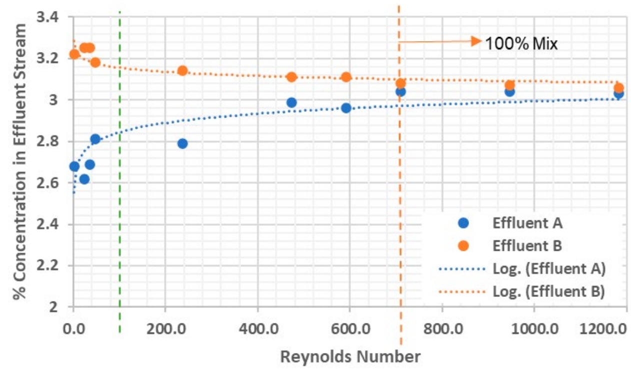

Fig. 5: Output concentrations vs Reynolds Number.

The X-style helical mixer was compared to an "H" style chip with a straight mixing zone, with the same hydraulic diameter of the X-style helical mixer. In both chips the mixing section is 16 mm long. The mechanism driving mixing in this case is pure diffusion. The theoretical time required for complete mixing using pure diffusion (at the same flow velocity as the X-style chip) is 10 minutes and 20 seconds. This is compared to resident times through the mixing section of the helical mixer of fractions of a second over the range tested. This means a diffusive mixer would require about 50-500 times more mixing channel length than the helical mixer alone, depending upon the Reynolds number (flowrate). Over the Reynolds numbers tested the H style effluent streams show little change in % concentration from input to output due to the very small residence time in the channel, where the reagents are in contact with each other.

CONCLUSION

LabSmith's uProcess components and Hummingbird Nano's mixing chips provide fast mixing, near zero dead volume, low swept volume and the ability to control the concentration of two output streams. Mixing is enhanced as compared to straight channeled chips for the Reynolds numbers tested. The effluent streams can then be used for further processing within the overall microfluidic system. Chips with different channel sizes and various repeatability requirements are available.

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