Mastering Mixing in Flow Chemistry: How Uniqsis Glass Static Mixers (GSMs) Drive Better Reactions

1. Introduction

Continuous flow chemistry offers chemists a safer, more efficient, and highly reproducible way to perform reactions. However, the true potential of flow chemistry can only be realized with effective mixing. Poorly mixed reagents can result in lower yields, reduced selectivity, and inconsistent product quality.

Mixing quality is dictated by flow regime, reactor design, and mixing technology. This article explores the different mixing regimes, provides real-world reaction examples, and explains why Uniqsis glass static mixers (GSMs) are a superior choice over alternative materials, especially when integrated into modules like the HotChip, ColdChip, and PhotoChip.

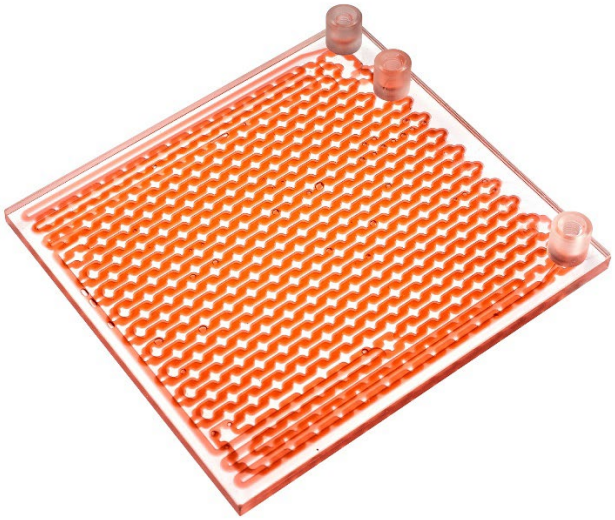

Figure 1: Uniqsis Large Format Glass Static Mixer

2. The Three Mixing Regimes in Flow Reactors

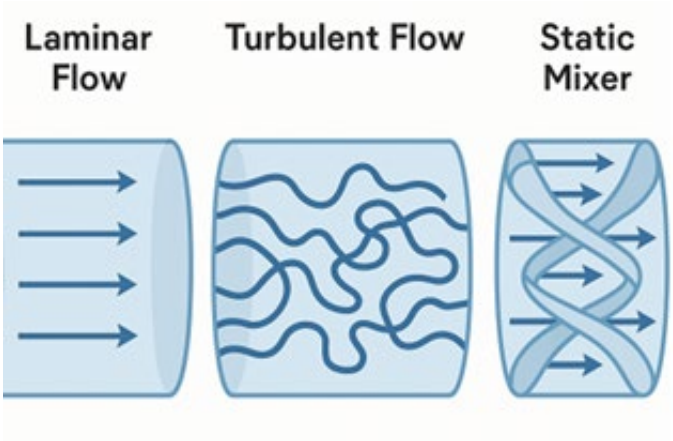

Figure 2: Graphical depiction of the three major mixing regimes

2.1 Laminar Mixing

- Occurs at low Reynolds numbers (Re < 2000), typical in microreactors.
- Mixing occurs mainly by molecular diffusion, which can be slower for viscous or immiscible fluids but is reproducible.
- **Example:** In photoredox catalysis with highly dilute solutions, laminar mixing may be sufficient because the reaction kinetics are slow, and molecular diffusion dominates.

2.2 Transitional Mixing

- Occurs over a range of intermediate Reynolds numbers, where partial eddies and vortices enhance mixing without full turbulence.
- **Example:** In liquid–liquid biphasic reactions (e.g., phase-transfer catalysis), transitional flow improves interfacial contact, enhancing mass transfer between phases.

2.3 Turbulent Mixing

- Occurs at high Reynolds numbers (Re > 4000), flow becomes chaotic and fully mixed.
- Ideal for fast, exothermic, or gas–liquid reactions where rapid homogenization is critical.
- **Example:** Nitration of aromatics or diazotization reactions benefit from turbulent mixing to avoid hot spots and maintain reaction selectivity.

3. Why Mixing Matters: Real Examples in Flow Chemistry

Here are some examples of how mixing directly affects flow chemistry outcomes:

- **Fast Exothermic Reactions (e.g., Grignard or Organolithium Chemistry)**
  These highly reactive intermediates require precise temperature control. Poor mixing can cause localized overheating, leading to side reactions or even safety hazards.
  Solution: Glass static mixers ensure rapid homogenization, eliminating hotspots and improving reaction reproducibility.

- **Gas–Liquid Reactions (e.g., Hydrogenation, Ozonolysis)**
  Gas–liquid mass transfer is often the limiting step. Without good mixing, the gas phase remains poorly dispersed.
  Solution: Structured Uniqsis glass static mixers create microbubbles, increasing gas–liquid interfacial area for faster reaction rates.

- **Liquid–Liquid Reactions (e.g., Phase-Transfer Catalysis, Biphasic Oxidations)**
  These rely on interfacial contact between two immiscible liquids. Laminar flow leads to segregated streams, reducing reaction efficiency.
  Solution: Static mixers continuously split and recombine streams, enhancing interfacial renewal and reaction yield.

- **Nanoparticle & Crystallization Processes**
  When mixing is inadequate, nucleation and growth become uncontrolled, leading to broad particle size distributions.
  Solution: Microstructured static mixers enable ultra-fast mixing to achieve uniform supersaturation and controlled particle sizes.

4. What Do Static Mixers Do?

Static mixers are internal structures placed within flow channels to:

- Continuously split and recombine streams
- Create radial mixing in laminar regimes
- Reduce diffusion lengths, improving homogenization
- Enhance mass and heat transfer without moving parts

They are passive devices—no external energy is needed beyond the pumping force of the fluids.

5. Material Comparison: Glass vs. Metal vs. PTFE Static Mixers

Property	Glass Static Mixers	Metal Static Mixers	PTFE Static Mixers
Chemical Resistance	Outstanding — compatible with acids, bases, and solvents	Good, but some acids can corrode metals	Excellent, but limited with certain organic solvents
Temperature Range	Cryogenic to >250 °C	High (>400 °C)	Limited (~200 °C)
Transparency	Yes — allows real-time visual inspection	No	Opaque
Contamination Risk	None — inert surface	Possible leaching of metals	Minimal
Mechanical Strength	High but brittle	Very high	Moderate
Cleanability	Smooth surfaces easy to clean	Can be harder to fully clean	Easy to clean but can deform

6. Why Glass Wins in Flow Chemistry:

From the table above it's clear that glass static mixers have many advantages over other materials;

- Transparency is invaluable for monitoring reactions, just as with a traditional round-bottomed flask.
- Optical transparency is essential for photochemical reactions.
- No risk of metal contamination in pharmaceutical applications.
- High purity, inert, and compatible with aggressive chemistries.

7. Uniqsis Glass Static Mixers: Designed for Continuous Chemistry

Uniqsis' glass static mixer modules are engineered specifically for continuous chemistry:

- **Compatible with the Uniqsis & Uniqsis Flow Chemistry range** – easily integrated into new or existing setups
- **High-performance mixing geometries** – including helical and interdigital split-and-recombine elements

- **Customizable lengths and diameters** – allowing optimisation for laminar, transitional, or turbulent regimes
- **Safe scale-up** – same mixing principles apply from microreactors to production-scale systems

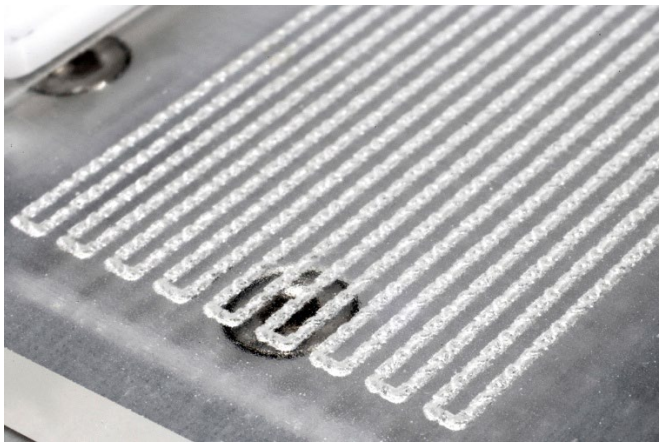

Figure 3: Image of the micro-structured channels in an Uniqsis GSM

8. Uniqsis Glass Static Mixers: Available options

Uniqsis' Glass Static Mixers are available in a range of geometries and sizes to suit your chemistry.

8.1 Compact Format Glass Static Mixers

Uniqsis' 'compact format' GSMs all share the same external dimensions (110 x 57 x 7.5 mm). They have smooth input pre-equilibration domains to ensure that reagent solutions are all at the same temperature as the glass prior to mixing. Fluidic connections are conveniently made using standard fittings.

Up to two compact GSMs can be fitted to the HotChip, ColdChip, Polar Bear GSM and PhotoChip reactor modules. These compact GSMs are available in volumes of 0.27, 1.6, and 5.0 mL and all utilise the same efficient 3D chicane mixing geometry that is effective at lower flow rates. This range also includes a "two-step" GSM chip that allows a reagent [A + B] + [C] application. The channel dimensions are approximately 1.0 mm ID (or less for the 0.27 mL GSM) but vary along the flow path to constitute many 'chicane' mixing domains.

8.2 Large Format GSMs

Uniqsis 'large format' GSMs also all share the same external dimensions (140 x 130 x 7.5 mm) and have smooth temperature equilibration domains prior to the mixing point. Fluidic connections are conveniently made using standard HPLC fittings.

These GSMs are designed for larger scale applications using either the HotChip, ColdChip, Polar Bear *Plus* GSM, and PhotoChip reactor modules. This format is available in 5.0, 10.0, and 20 mL options.

9. Conclusion

In continuous flow chemistry, mixing is not optional—it's fundamental. Different reactions demand different mixing regimes, from diffusion to high-intensity turbulent mixing. By understanding your reaction's needs and incorporating the right equipment, you can unlock better selectivity, higher yields, and safer operation.

Uniqsis glass static mixers provide a versatile, chemically resistant, scalable, and optically transparent solution for continuous chemistry applications.

When integrated into any flow chemistry system with the HotChip, ColdChip, Polar Bear *Plus* GSM and PhotoChip modules, Uniqsis glass static mixers deliver precise, reproducible, and scalable mixing performance.

For further information please contact our technical support team via email at enquiries@asynt.com.