High-Throughput Chemistry and Biology: Photons, Particles and Droplets

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Abstract

It is recognized that when compared to macroscale instruments, micro and nanofluidic systems engender a number of distinct advantages with respect to speed, analytical throughput, reagent usage, process control, automation and operational and configurational flexibility. Such systems provide new operational paradigms and predictions about how molecular synthesis and analysis might be revolutionized in the coming years. My talk will describe on-going work in the following areas:

Photons
Optical detection techniques are crucial in molecular analysis due to a recognised need for rapid, on-line measurements at low concentrations. Over the past few years we have developed a range of optical methods for probing small volume systems. I will briefly discuss recent studies in which we have applied fluorescence lifetime imaging and vibrational spectroscopies to high-throughput, high-sensitivity analysis in small-volume environments.

Particles
Nanomaterials exhibit optical and electronic properties that depend on their size and shape, and are seen as tailored precursors for functional materials in biological sensing and optoelectronics. These critical dependencies dictate that 'bottom-up' approaches for nanomaterial synthesis must provide for fine control of the physical dimensions of the final product. Synthetic routes have attracted interest owing to their versatility and ease of use, but some form of post-treatment is normally required to extract the desired particle size. In principle, microfluidic systems provide an ideal medium for nanoparticle production. Since both mass and thermal transfer is rapid, temperatures may be defined with precision or varied on short timescales. Additionally, reagents can be rapidly and efficiently mixed to ensure homogeneous reaction environments, while allowing for additional reagents to be added at predefined times. Specifically, I will discuss how microfluidic reactors can be integrated with machine learning methods to define 'intelligent' reactors capable of synthesising nanoparticles of defined sizes and shapes.

Droplets
Many researchers have exploited the formation of droplets in microfluidic systems to perform a variety of analytical processes. Of particular note are those that use flow instabilities between two immiscible fluids. Droplets can be formed spontaneously when multiple laminar streams of aqueous reagents are injected into an immiscible carrier fluid. These droplets define picoliter volumes, and because each droplet is isolated from channel surfaces and other droplets, each one acts as an individual reaction vessel. Importantly, droplets can be generated at kHz frequencies, meaning that millions of individual reactions can be processed in very short times. I will report recent advances in this area with particular reference to high throughput analyses and basic droplet manipulations.

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