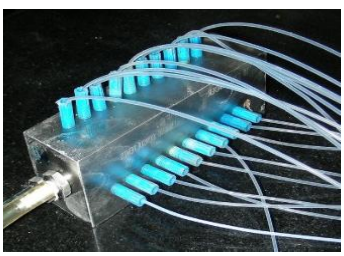
Chemical microprocessing

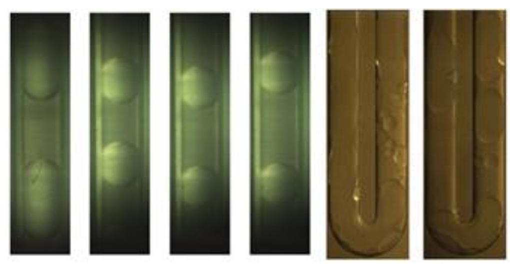
Chemical Microprocessing using microfluidic platforms is one of the strengths of Chemical Engineering Division. Starting from a humble beginning in accessing feasibility of carrying out solvent extraction in commercial, imported etched-in-glass microchannels a long way has been traversed over the last decade. Microreactors being used at ChED now are made from components like microcapillaries and microfluidic junctions which are readily available and/or fabricated indigenously. Chemical microprocessing has been demonstrated for a wide range of applications as described below.

Solvent extraction: A compact multistage solvent extraction method based on microreactor technology was demonstrated at 10 LPH processing capacity. The system was demonstrated for separation and purification of uranium from lean streams. Indigenous microfluidic flow distributors were designed and tested. Very high specific extraction rates in short contact times were demonstrated. Capitalizing on the experience gained, compact and efficient microfluidic solvent extraction modules were designed, and demonstrated for purification of radiopharmaceutical grade ^{64}Cu in collaboration with RC&IG.



MDIMJ

Microfluidic extraction of ^{64}Cu

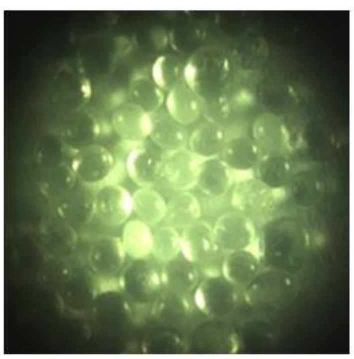


Flow patterns in microchannels

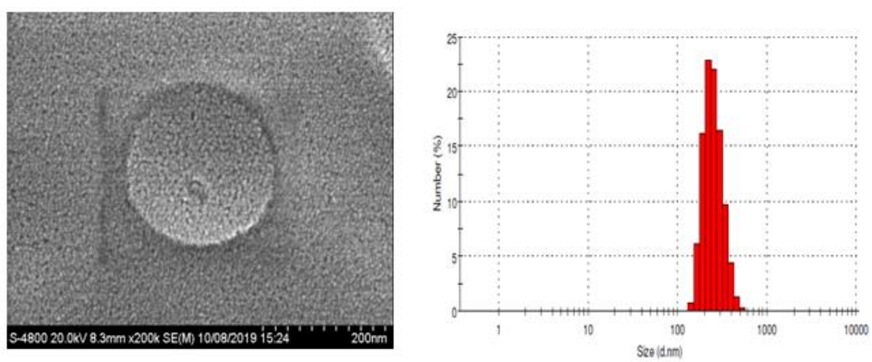
Ionic liquid synthesis: One of the major advantages of microreactor technology is its excellent heat transfer characteristic which is ideal to tame highly exothermic reactions. Harnessing this, microreactors have been used to synthesize a wide variety of imidazolium-based ionic liquids in solvent-free and continuous mode of operation. Microfluidic platforms that can produce imidazolium-based ionic liquid (e.g. 1-butyl-3-methylimidazolium bromide) at scale of tens of kilogram per day have been designed and tested. Space-time-yields that can be achieved is around two orders of magnitude higher than conventional batch method.

Different types of ionic liquids synthesized in microreactor

Polymer synthesis**:** Simple microcapillary based microfluidic systems have been designed and tested to carry out polymerization reaction under flow. Emulsion polymerization was successfully carried out to synthesize nanoparticles of polystyrene (PS), polyacrylate (PA) and polymethylmethacrylate (PMMA). Microreactor technology was also leveraged to synthesize monodispersed polymeric hydrogels (for example polyacrylamide (PAM) beads)

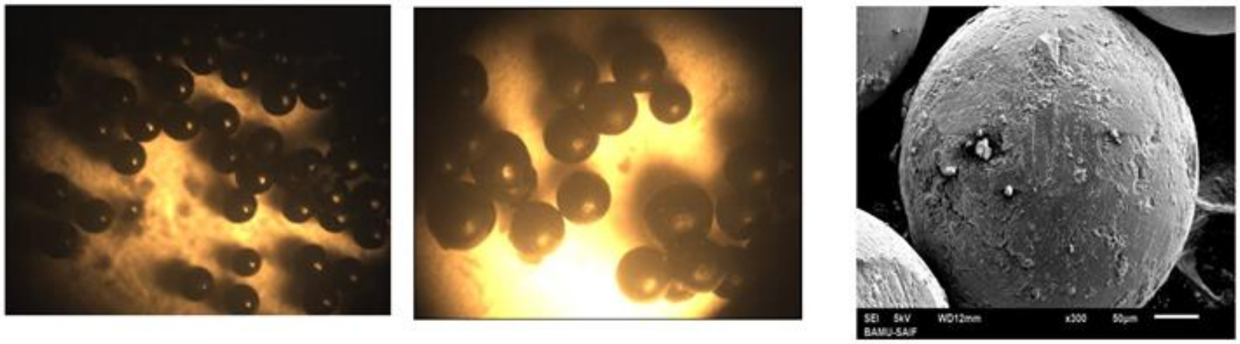


Polymer (PAM) hydrogels



PS nanoparticles

Microparticles**:** A simple microfluidic system was designed and tested to continuously synthesize monodispersed microparticles in a sustained and repeatable fashion. This represented a successful attempt to conduct sol-gel reaction under flow conditions inside a microchannel. The technique was demonstrated for chromium, aluminum and scandium hydroxide microparticles. Monodispersed microparticles of different size ranges could be synthesized simply by changing the flow conditions.

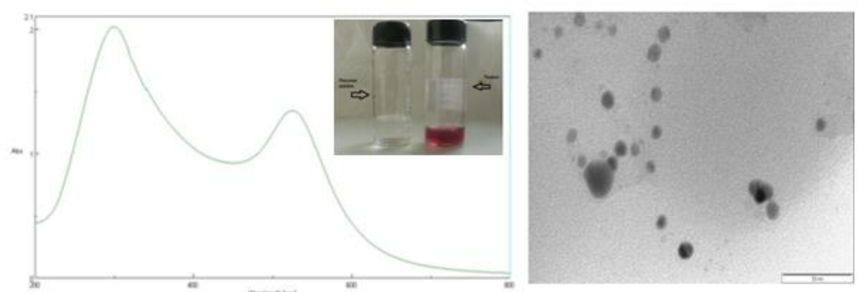


d_c = 0.8 mm

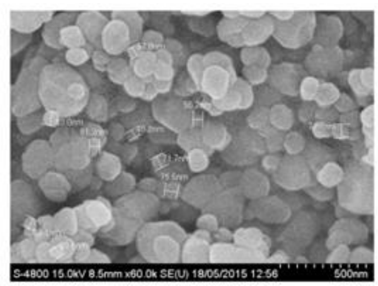
d_c = 2 mm

Chromium hydroxide microparticles

Nanoparticles: Another feature of microreactor technology is its ability to produce highly monodispersed nanoparticles. This feature was harnessed and microreactors were designed, and demonstrated for synthesis of monodispersed nanoparticles. Examples include flow synthesis of $BaSO_4$ nanoparticles and flow synthesis of ultrafine radioactive gold nanoparticles (^{198}Au) for biomedical applications.



Flow synthesis of Au nanoparticles



$BaSO_4$ nanoparticles