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Nanoparticle formation by block copolymer directed rapid precipitations—Flash NanoPrecipitation

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With widespread interest in the generic “nano” attention has been focused on strategies of making small particles. High-value applications that drive new process innovation include very hydrophobic pharmaceutical actives, dyes and pigments for ink jet printing, or the dispersal of highly toxic insecticides on carriers. While it is relatively easy to make inorganic nano-particles, for example CdS particles, it is much more challenging to make nanoparticles from low surface energy organic solids. Strategies for forming nano particles vary from supercritical spraying, supercritical freezing, milling, solvent exchange precipitation, and imbibing into polymeric micelles. The solute and process combine to give differences in crystalline/amorphous products, individual particles/agglomerates, and uniformity/polydispersity of sizes. We will give an overview of the techniques and the classes of products that each addresses. We have developed a new technology that has two components: (1) rapid and tailored micromixing in an impinging jet, and (2) novel block copolymer stabilizers. The impinging jet process allows the production of nano-particles by: 1) elimination of mass transfer limitations and compositional gradients within 10 ms as determined by independent measurements with competitive-parallel reactions, 2) production of high supersaturations and solute concentrations so that high production rates can be obtained, and 3) control of particle size by stabilization of the particle using block copolymer self-assembly. The process depends critically on control of three time scales: particle nucleation and growth, block copolymer micellization, and polymer adsorption on the particle to produce steric stabilization. We present data on characterization of the mixing times using competitive reactions, data on polymer micellization kinetics, and results on the successful production of β -carotene and taxol particles with control of the particle size between 40 nm to 600 nm. A range of block copolymers have been used : PS-b-PEO, PBA-b-PAA, and PCL-b-PEO. Homogeneous rapid nucleation and growth produces particle size distributions that are much narrower than those obtained by alternate size-reduction or precipitation routes, and results in a decreased tendency to Ostwald ripen.