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(57) Abstract :
The present invention relates to a solvent-free reactive-extrusion three-dimensional printing process for manufacturing biodegradable syringe assemblies including syringe barrels, plungers, and associated syringe components. The process comprises selectively depositing a primary biodegradable polymer as inner rasters of a syringe barrel and/or plunger and selectively depositing a secondary biodegradable toughening polymer in perimeter rasters through toolpath-gated dual-stream extrusion to form a compositionally differentiated wall structure. The process further comprises programmed interlayer thermal annealing to generate a radial crystallinity gradient between an outer wall region and an inner wall region of the syringe barrel, inner-bore thermal reflow to reduce lumen roughness, surface activation of the inner bore by plasma, corona, ultraviolet, ozone treatment, or combinations thereof, and solvent-free vapor grafting of antimicrobial and anti-stiction functional agents onto the activated lumen surface. The invention further provides a biodegradable syringe assembly having enhanced hoop strength, reduced inner-bore roughness, antimicrobial inner surface functionality, silicone-free low-friction plunger actuation, and improved dimensional stability. The invention also relates to an integrated manufacturing system comprising dual-stream extrusion printing, thermal annealing, inner-bore reflow, surface activation, and vapor grafting modules configured for carrying out the disclosed process.

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