Development and fabrication of nanoporous silicon-based bioreactors within a microfluidic chip

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Multi-scale lithography and cryogenic deep reactive ion etching techniques were used to create ensembles of nanoporous, picolitre volume, reaction vessels within a microfluidic system. The fabrication of these vessels is described and how this process can be used to tailor vessel porosity by controlling the width of slits that constitute the vessel pores is demonstrated. Control of pore size allows the containment of nucleic acids and enzymes that are the foundation of biochemical reaction systems, while allowing smaller reaction constituents to traverse the container membrane and continuously supply the reaction. In this work, a 5.4 kb DNA plasmid was retained within the reaction vessels and labeled under microfluidic control with ethidium bromide as an initial proof-of-principle. Subsequently, a coupled enzyme reaction, in which glucose oxidase (GOX) and horseradish peroxidase (HRP) were contained and fed with a substrate solution of glucose and Amplex Red™ to produce fluorescent resorufin, was carried out under microfluidic control and monitored using fluorescent microscopy. The fabrication techniques presented are broadly applicable and can be adapted to produce devices in which a variety of high aspect ratio, nanoporous silicon structures can be integrated within a microfluidic network. The devices shown here are amenable to being scaled in number and organized to implement more complex reaction systems for applications in sensing and actuation as well as fundamental studies of biological reaction systems.