Solvent-Resistant Elastomeric Microfluidic Devices and Applications
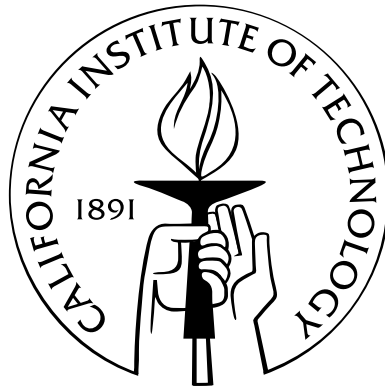
Thesis by

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For my parents, Laurie and Erling, for their love, support, guidance, inspiration, encouragement, and the values they have taught, and for instilling in me a drive to "do my best" in whatever I choose to do.

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Abstract

Microfluidics is increasingly being used in many areas of biotechnology and chemistry to achieve reduced reagent volumes, improved performance, integration, and parallelism, among other advantages. Though early devices were based on rigid materials such as glass and silicon, elastomeric materials such as polydimethylsiloxane (PDMS) are rapidly emerging as a ubiquitous platform for applications in biotechnology. This is due, in part, to simpler fabrication procedures and to the ability to integrate mechanical microvalves at vastly greater densities. For many applications in the areas of chemical synthesis and analysis, however, PDMS cannot replace glass and silicon due to its incompatibility with many solvents and reagents.

Such areas could benefit tremendously from the development of an elastomeric microfluidic device technology that combines the advantages of PDMS with the property of solvent resistance. Simplified fabrication could increase the accessibility of microfluidics, and the possibility of dense valve integration could lead to significant advances in device sophistication. Applications could be more rapidly developed by design re-use due to the independence of mechanical valves on fluid properties (unlike electrokinetic pumping), and the property of permeability could enable novel fluidic functions for accessing a broader range of reactions than is possible in glass and silicon.

The first half of this thesis describes our strategies and efforts to develop this new enabling technology. Several approaches are presented in Chapter 3, and two particularly successful ones, based on new elastomers (FNB and PFPE), are described in Chapters 4 and 5. Chapter 6 describes a novel method of fabricating devices from 3D molds that could expand the range of useful elastomers.

The second half of this thesis discusses microfluidic combinatorial synthesis and high throughput screening—applications that take particular advantage of the ability to integrate thousands of

individual valves and reaction chambers. Chapter 7 introduces several scalable device architectures and presents results of preliminary steps toward the synthesis of combinatorial DNA and peptide arrays. A novel method of performing universal gene expression analysis with combinatorial DNA arrays is described in Chapter 8 and an algorithm for predicting relationships among genes from gene expression array data is presented in Chapter 9.

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