

MANIPULATING FLUIDS: ADVANCES IN
MICRO-FLUIDICS, OPTO-FLUIDICS AND
FLUIDIC SELF ASSEMBLY

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Saurabh Vyawahare

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Saurabh Vyawahare

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The efforts of most human-beings are consumed in the struggle for their daily bread, but most of those who are, either through fortune or some special gift, relieved of this struggle are largely absorbed in further improving their worldly lot. Beneath the effort directed toward the accumulation of worldly goods lies all too frequently the illusion that this is the most substantial and desirable end to be achieved; but there is, fortunately, a minority composed of those who recognize early in their lives that the most beautiful and satisfying experiences open to humankind are not derived from the outside, but are bound up with the development of the individual's own feeling, thinking and acting. The genuine artists, investigators and thinkers have always been persons of this kind. However inconspicuously the life of these individuals runs its course, none the less the fruits of their endeavors are the most valuable contributions which one generation can make to its successors....

-Albert Einstein in Emmy Noether's obituary (1935)¹

¹ Quote in my graduate school application, circa 2001. I am happy to report that grad school has not blunted this belief, as yet.

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ABSTRACT

This dissertation describes work in three inter-related areas – micro-fluidics, opto-fluidics and fluidic self-assembly. Micro-fluidics has gotten a boost in recent years with the development of multilayered elastomeric devices made of poly (dimethylsiloxane) (PDMS), allowing active elements like valves and pumps. However, while PDMS has many advantages, it is not resistant to organic solvents. New materials and/or new designs are needed for solvent resistance. I describe how novel fluorinated elastomers can replace PDMS when combined with the three dimensional (3-D) solid printing. I also show how another 3-D fabrication method, multilayer photo-lithography, allows for fabrication of devices integrating filters. In general, 3-D fabrications allow new kinds of micro-fluidic devices to be made that would be impossible to emulate with two dimensional chips.

In opto-fluidics, I describe a number of experiments with quantum dots both inside and outside chips. Inside chips, I manipulate quantum dots using hydrodynamic focusing to pattern fine lines, like a barcode. Outside chips, I describe our attempts to create quantum dot composites with micro-spheres. I also show how evaporated gold films and chemical passivation can then be used to enhance the emission of quantum dots.

Finally, within fluids, self assembly is an attractive way to manipulate materials, and I provide two examples: first, a DNA-based energy transfer molecule that relies on quantum mechanics and self-assembles inside fluids. This kind of molecular photonics mimics parts of the photosynthetic apparatus of plants and bacteria. The second example of self-assembly in fluids describes a new phenomena - the surface tension mediated self assembly of particles like quantum dots and micro-spheres into fine lines. This self assembly by capillary flows can be combined with photo-lithography, and is expected to find use in future nano- and micro-fabrication schemes.

In conclusion, advances in fluidics, integrating materials like quantum dots and solvent resistant elastomers along with 3-D fabrication and methods of self assembly, provide a new set of tools that significantly expand our control over fluids.

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