Abstract:

Precise placement of individual biological cells is desirable to obtain accurate quantitative data for a variety of experiments. In this project, we intend to manipulate cells by tagging them with paramagnetic beads and then electromagnetically maneuvering the beads. For this purpose, we are trying to develop a microelectromagnetic device, consisting of a two-dimensional array of current-carrying wires, which can be used to create localized magnetic field patterns that can be configured to manipulate beads with microscopic precision. Thus far, the results indicate that the magnetic fields produced by current loops are capable of trapping and manipulating beads when a substantial amount of current is applied.

Summary of Research:

Neuronal function and cellular release mechanisms are of great importance in understanding human health and certain neurological diseases including Parkinson’s disease. Various types of devices have therefore been developed so far to study such release mechanisms. Although these compact on-chip systems allow for fast, repeatable biological experiments at low cost with only a small amount of biological sample, one of their main difficulties is positioning and manipulating the individual sample cells with high precision at the microscopic scale. The techniques currently in use for single-cell isolation and manipulation include optical tweezers and dielectrophoresis. However, these techniques are far from ideal; one has a tendency to damage the cell surface, while the other introduces excessive signal noise.

In this project, we are trying to develop a technique based on a microelectromagnet to manipulate biological cells attached to paramagnetic beads with high precision. The magnetic manipulation scheme was chosen because of the biocompatibility of magnetic fields. Previously, electromagnetic traps, rings and guides have been designed to manipulate neutral atoms, magnetic nanoparticles, etc. The proposed device shall consist of a microfluidic channel and an array of lithographically defined platinum wires on a silicon substrate (Figure 1). Passing sufficient amounts of current through these wires will create localized magnetic field patterns that can be configured to precisely manipulate beads at the microscopic scale. The device can theoretically control almost any kind of

Figure 1: Geometry of finite rectangular wire used to calculate magnetic fields.

Figure 2: 3D magnetic field profile at optimum insulation height above square current loop.
magnetic particle, including biological cells attached to paramagnetic beads. In future, such a device can be integrated with on-board electronics, such as electrodes and amplifiers, which would allow for simultaneous positioning of cells as well as real-time measurements of cellular activity. In addition, it can also be used to assemble artificial tissues and investigate intercellular communications.

The magnetic field generated by the device is directly proportional to the current and inversely proportional to the distance, whereas the magnetic force generated by the field is directly proportional to the gradient of the field. As shown in Figure 3, the magnetic field profile above a current-carrying loop varies with height. Therefore, in the context of cell manipulation, the height of the insulation layer above the loop is critical. Based on our experiments with a variety of insulation heights, the optimum height has been determined to be $0.64r$ (where $r$ is the radius of the loop) for circular current loops and $\geq 0.5p$ (where $p$ is the wire pitch) for square-shaped loops (Figure 2).

Since circular current loops can only be constructed with a single metal layer, only a small amount of current can be used before power dissipation, due to internal resistance, leads to overheating and device failure. In addition, a single metal layer also limits the field gradient that can be obtained because of the closed ring trap geometry (Figure 4). Therefore, we are currently experimenting with square-shaped current loops fabricated using two stacked metal layers. Using MATLAB simulations and theoretical analysis, it is evident that using two metal layers instead of one offers a great deal of improvement in device operation and functionality.

### References: