The Self Assembly of Microspheres in a Microchamber

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Abstract:

Frequently, applications of microspheres require a methodology for selectively placing the spheres. This paper discusses the creation of a methodology for placing a near monolayer of microspheres and nanospheres inside of microchambers (ranging in size from approximately 100 μm to approximately 3 mm) attached to two channels (20 μm in diameter). Uniform sphere distribution is prohibited by two internal flow pattern effects: evaporation and capillary effect.

Capillary forces cause the spheres to be pulled toward the edge of the microchamber and into the two channels. In addition, uneven evaporation causes an outward flow pattern that causes the spheres to form a ring upon drying, a ring that is commonly referred to as a "coffee ring." To overcome these difficulties, a polydimethyl siloxane (PDMS) mask allows a selected area of the microchamber to be treated with oxygen plasma, creating an interface between the treated area of the microchamber and the non-treated area of the channels. This causes the water containing the spheres to stay out of the channels, thereby reducing the capillary force that draws the beads to the edge of the chamber. Heating the sphere-containing droplet altered the flow pattern of the spheres in the droplet, and, consequently, the "coffee ring" was less pronounced.

Further experimentation with this method could lead to a more uniform monolayer of spheres.

Introduction:

The Microscale Life Sciences Center is a collaboration of 10 investigators from various departments at the University of Washington and the Fred Hutchinson Cancer Research Center. "The goal of the Microscale Life Sciences Center at the University of Washington is to apply microsystem-based devices for the multiplexed, real-time, multiparameter analysis of individual cells" [1]. This desire to measure multiple cellular parameters necessitates the creation of a system for capturing single cells and observing, in real time, various parameters of the cell and its surrounding environment.

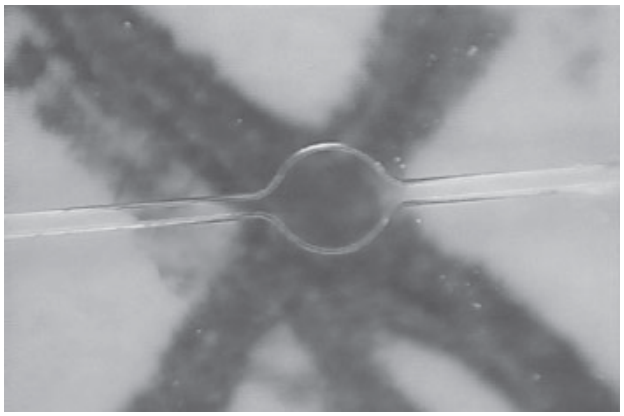

Figure 1: The geometry of the microchamber.

The system currently being developed is attempting to utilize microchambers with a geometric structure similar to the microchamber shown in Figure 1. Once a cell is trapped inside of the chamber, another sub-system is needed to monitor parameters of the cell and its surrounding area, namely that of the micro-chamber. Microspheres and nanospheres, with chemically modified shell layers, have been show to be effective in a variety of bio-sensing applications [2].

Effective utilization of microspheres as biosensors requires a methodology for the selective placement of the microspheres inside of the microchamber. This paper describes the creation of a methodology that leaves a near monolayer of 1 μm beads inside of a microchamber.

Materials:

The microbeads primarily used were 1, 4.5, and 10 μm polystyrene beads from Polysciences, Inc. Sphere-containing water droplets were placed on both flat, glass substrates and etched glass substrates. A polydimethyl siloxane (PDMS) mask was used to selectively treat various areas of the glass substrates with oxygen plasma.

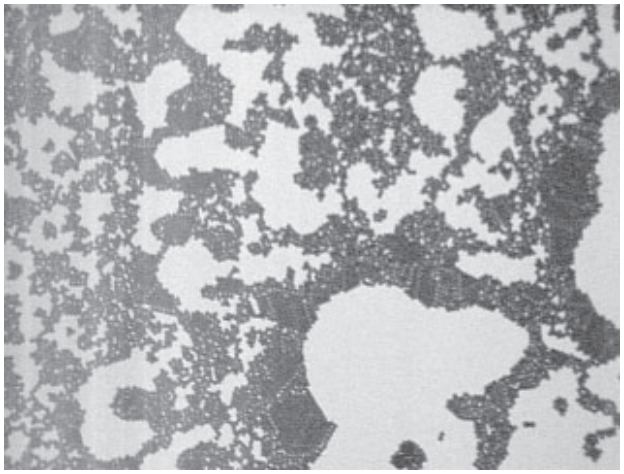

Figure 2: Inner portion of a dried droplet.

Results and Discussion:

Figure 2 demonstrates the sphere distribution in the inner portion of the droplet without any treatment, where the 10 microliter drops containing 10 μm beads were placed on a glass substrate and allowed to dry. The spheres in the inner portion of the droplet are very disordered. In addition, there is a thick ring of microspheres around the edge of the dried droplet. This ring is not pictured, but it resembles the rings that form when one spills a droplet of coffee on a flat surface and allows the droplet to dry unmolested.

Both the disorder of the dried beads and the formation of the "coffee ring" are undesirous and are caused by the flow pattern of the droplet's fluid as the droplet dries. As the liquid at the edge of the droplet evaporates, fluid flows from the inside of the droplet to the contact line on the outside of the droplet. Thus, a fluid-flow pattern from the center of the droplet to the outside of the droplet is established. A summary of this phenomenon is discussed in [2]. The inside to outside flow pattern pushes the majority of the microspheres to the edge of the droplet leaving a "coffee ring" at the edge of the dried droplet and a disorderly scattering of microspheres in the center of the dried droplet. This inside to outside flow pattern is undesirous because neither a ring nor a disorderly scattering of microspheres is conducive to placing a uniform monolayer.

In order to change the flow pattern, the droplets were placed on the substrate, and the substrate was heated on a hot plate. The new flow pattern caused the microspheres to move to the center of the droplet. Placing the microchamber in the center of the droplet and using the hot plate to move the microspheres to the center of the droplet was a method of placing microspheres in the microchamber.

The second problem was due to the capillary forces and the geometry of the chamber. The capillary forces would pull the spheres towards the microchannels and edges of the microchamber. This problem was countered by creating a hydrophobic-hydrophilic interface at the point where the microchannel entered the microchamber. This interface was created by using a PDMS mask to cover only the microchannels while leaving the microchamber exposed and treating the exposed microchamber and only the exposed microchamber with oxygen plasma. The treatment rendered the microchamber hydrophilic relative to the microchanels. The hydrophobic-hydrophilic interface acted as a blockade and reduced the effect of the capillary forces.

Figure 3 shows the results without the interface and the results with the interface. Further experimentation with the methods of changing the flow pattern and methods of plasma treatment should lead to even better results.

Acknowladgements:

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References:

[1] Lindstrom and Meldrum. "Life-on-a-chip." www.nature.com/reviews/micro. November 2003. Volume 1. pp 158-164.

[2] Goody and McDevitt. "Multishell Microsensors...". J. AM. Chem. Soc. Vol 125, No. 10, 2003.

[3] Deegan, et al. "Capillary Flow..." Nature. Vol. 389. 23 Oct. 1997.

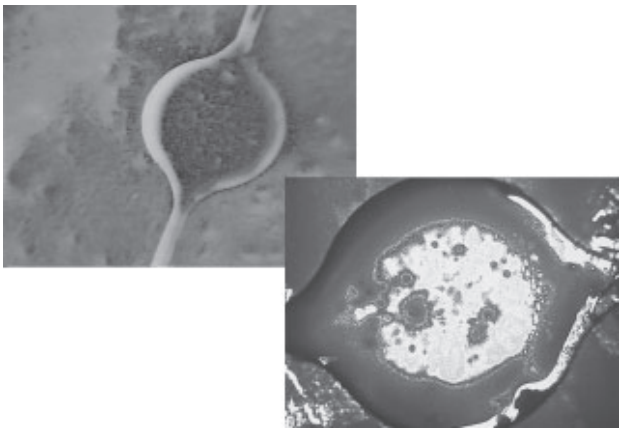

Figure 3: Chamber without interface on top and with interface on bottom.