

A DYNAMIC SPOTTING METHOD FOR SPLIT-PIN BASED MICROARRAYS

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Abstract

The authors propose a non-contact spotting concept for split-pin based microarrays utilising dynamic control of the trajectory of the split-pin. Numerical simulation demonstrates that this novel method not only avoids the necessity of the pin tip striking the surface of the substrate, but also offers a new mechanism to realize spot-volume-on-demand, as well as enhance the uniformity of sample spots.

Keywords: liquid dispensing, split pin printing, microarray, CAD, microfluidics

1. Introduction

Microarray technology was first introduced by the Brown and Davis groups [1][2][3] to deposit pre-synthesized oligonucleotides or PCR products onto solid substrates. The substrates are then processed and analyzed in parallel. This powerful technology enables the simultaneous analysis of thousands of sequences of DNA, and has found wide use in genomics (for instance, [4]), and more recently, in proteomics [3].

Pin based liquid sample deposition (spotting) is widely employed due to its low cost, simplicity and robustness[1]. Figure 1 shows a split-pin fabricated by the Brown group. The pin is first dipped into the sample solution and a small volume of fluid is transferred into the slot. The pin is then guided to “tap” the substrate leaving a spot of the sample.

The tapping force required to deposit a sample spot on the substrate is not insignificant [1]. Such direct contact can lead to mechanical damage to the pin tips.

In addition, the sample droplet volume is affected by the speed at which the pin strikes the surface (for example, 2cm/sec [1]), which depends on the local mechanical contact property of the substrate - it can therefore be a major source of droplet volume disparity.

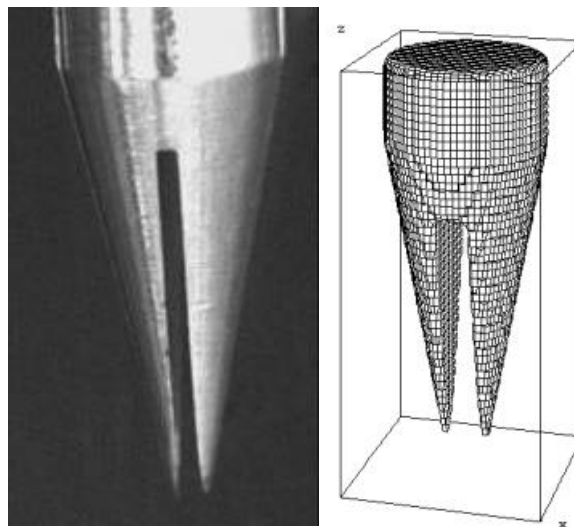


Fig. 1: At left is a split-pin fabricated by Brown group. A fine slot is machined into the end of the pin to accommodate liquid sample (courtesy professor Patrick O. Brown, Stanford University). At right shows solid structure and meshes used in numerical simulations.

2. A Non-Contact Pin Printing Concept: Dynamic Control of Pin Trajectory

A split-pin based non-contact spotting method is described here, that uses precise control of

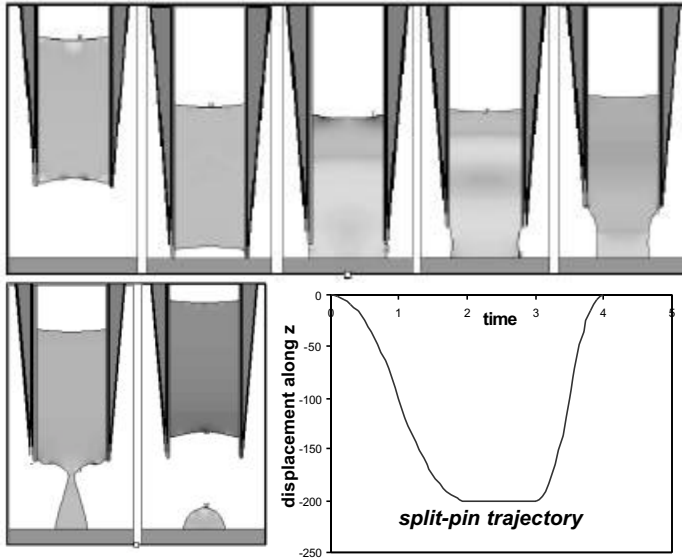


Fig. 2: Time sequence of liquid sample spotting. Motion of the split-pin is defined as shown trajectory. Frames are corresponding to 0, 1.8, 3.3, 3.5, 3.6, 3.8, 4.0 milliseconds. Minimum distance between pin tip and substrate is $2 \mu\text{m}$.

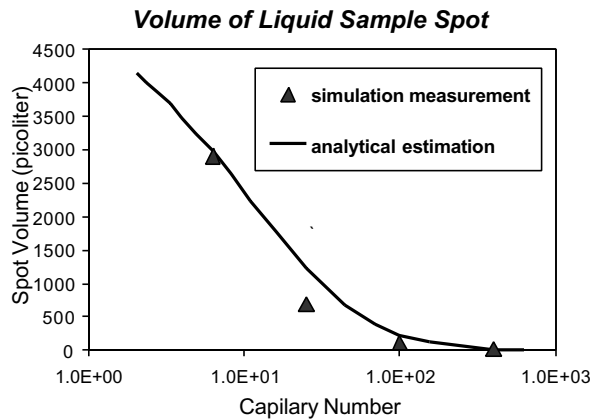


Fig. 3: Adjusting pin's pulling velocity can actively control the spotted liquid volume. Measured results are from numerical simulation, which agree with analytical estimation.

the pin trajectory. The displacement of the pin in the spotting sequence is shown in Figure 2 using numerical simulation [5][6]. The sample spot is deposited on the surface without tapping, by triggering the required instability to break the droplet through the acceleration of the pin away from the substrate. This approach overcomes the disadvantages of the conventional approach described above. This spotting approach enhances the uniformity of volume of sample spots. Furthermore, it offers a new mechanism to actively control the spot volume, or *spotting-volume-on-demand*. This can be accomplished by adjusting the pin's pulling velocity – spot sizes from 1-1000 pL can be deposited as shown in Figure 3.

The results in Figure 3 are compared with the analytical estimate,

$$V = \frac{\pi}{3} \tan \theta \left(\frac{a \cdot \cos \theta}{\cos \theta + \sin \theta + \sin(4\sqrt{Ca} - \theta)} \right)^3$$

where V is droplet sample volume, capillary number $Ca = 2\sigma/(\rho u^2 a)$, θ static contact angle, a dimension of the slot, σ surface tension coefficient, u average pin pulling velocity. The agreement between numerical and analytical measurements is very good, as the figure shows.

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