SUPERHYDROPHOBIC SURFACES FOR MICROFLUIDIC APPLICATIONS

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Abstract

Protein adsorption is of major importance in many contemporary research fields including biotechnology and materials science. Chemical modification of surfaces provides a simple and direct way of controlling the nature of protein surface interactions. In the current studies, we demonstrate the use of superhydrophobic surfaces within microfluidic systems to allow almost complete removal of adsorbed protein under flow conditions. Our aim is to use such 'surface technology' in PCR microfluidic devices for continuous flow PCR to hinder enzyme loss due to adsorption and therefore increase the efficiency of the reaction.

Keywords: PCR, surface adsorption, superhydrophobic surfaces, ZnO

1. Introduction

The most investigated biological reaction within microfluidic systems is DNA amplification via the polymerase chain reaction (PCR). A variety of microfabricated devices for PCR have been reported and in most improvements in reaction times, sample throughput and reaction efficiency have been observed. An essential feature of all such developments is improved thermal and mass transfer on the small scale. Heat can be rapidly transferred to and removed from reaction environments allowing temperatures to be controlled uniformly throughout the sample volume. Unfortunately, when compared with conventional macroscale thermocyclers for PCR, microfluidic environments are typicallycharacterized by extremely high surface-to-volume ratios. This means that surfaces play a dominant role in defining the efficiency of PCR through increased molecule-surface interactions. In a multi-component reaction system where the concentration of several components needs to be maintained the problem is particularly complicated. For example, inhibition of PCR is commonly observed due to polymerase adsorption at chip walls [1].

A number of surface passivation methods have been employed to reduce surface-molecule interactions within microchannels and thus create inactive surfaces that generate minimal interference with PCR. For example, silanization followed by dynamic coating [2][3][4] or polymerization steps [5] have been demonstrated with varying degrees of

success. Interestingly, surface treatments which involve a silanization step followed by coating with polyvinylpyrrolidone (PVP) and polyethylene glycol (PEG) have been performed to yield surfaces with contact angles of 95º and 70º. Since such coating methods often demonstrate inconsistent results we have investigated a new approach for generating superhydrophobic microchannel surfaces.

2. Experimental

In the current studies we have generated superhydrophobic surfaces with contact angles in excess of 150º, to hinder protein adsorption, particularly under flow conditions. Aqueous solutions in contact with some superhydrophobic surfaces are suspended by bridging-type wetting, and therefore the fraction of the surface in contact with the aqueous layer is significantly lower than for a flat surface, Figure 1. In addition, the non-wetted areas allow slippage between water and the surface, allowing zero flow boundary conditions to be broken and therefore greatly increasing flow rates near the wall for a given bulk flow rate or pressure drop. This would increase the shear stress on material, such as protein, adhered to the superhydrophobic surface.

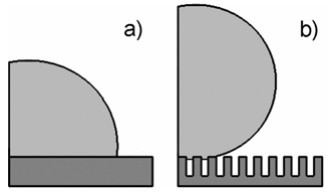


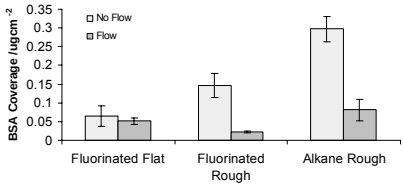
Figure 1. Wetting on a) hydrophobic and b) superhydrophobic surfaces

Glass microscope slides were used as flat substrates and slides coated with a porous silica sol-gel film were used as rough substrates. Surfaces were then chemically coated with either a fluorocarbon (Grangers Wash-In Solution) or trimethylchlorosilane (Aldrich). Adsorption of two serum proteins (fibrinogen and albumin) onto flat and rough surface was assessed using a Nano Orange fluorescent assay (Molecular Probes). This method allows accurate determination of protein concentration down to the ng/ml range. Further studies using albumin were conducted to examine the effects of flow on protein desorption and variation between alkane and fluorinated surfaces.

3. Results and Discussion

Albumin was found adsorb in higher amounts to rough surfaces than to flat. After surface washing the amount of protein remaining on flat surfaces is only slightly reduced, whereas for rough surfaces significant protein desorption is observed (Figure 2).

Additionally, albumin is observed to interact more strongly with fluorinated surfaces than alkane terminated surfaces. Under flow (washing) conditions adsorbed protein is removed



from the superhydrophobic surfaces more efficiently than from the hydrophobic surfaces.

Figure 2. Protein adsorption on hydrophobic and superhydrophobic surfaces with varying chemistry

4. Conclusion

It is observed that under flow conditions protein can be removed from superhydrophobic surfaces, with more pronounced desorption occurring from fluorinated surfaces. Presented studies also include protein adsorption measurements on superhydrophobic surfaces containing copper hydroxide or zinc oxide needles (Figure 3). It is expected that nanostructured surfaces of this kind can be used to precisely control surface molecule interactions within microfluidic systems. Moreover, it is hoped that control of the morphology of such nanostructured surfaces can be used to significantly reduce the strength of protein-surface binding under both static and flow conditions.

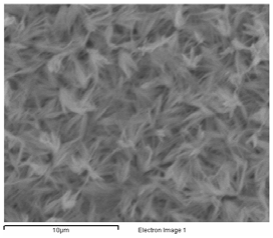


Figure 3. TEM image of copper hydroxide needles

Acknowledgements

The author's would like to thank Smiths Detection Plc for the provision of a research studenship

References

1. Krishnan, M., D.T. Burke, and M.A. Burns, .Analytical Chemistry, 2004. **76**(22): pp. 6588-6593.
2. Obeid, P.J., et al., Analytical Chemistry, 2003. **75**(2): pp. 288-295.
3. Kopp, M.U., A.J. de Mello, and A. Manz, Science, 1998. **280**(5366): pp. 1046-1048.
4. Chiem, N. and D.J. Harrison, Analytical Chemistry, 1997. **69**(3): pp. 373-378.
5. Munro, N.J., A.F.R. Huhmer, and J.P. Landers, Analytical Chemistry, 2001. **73**(8): pp. 1784-1794.