Analyte Capture from Liquid Samples: Size Matters.

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MPC Micro Purification Chip

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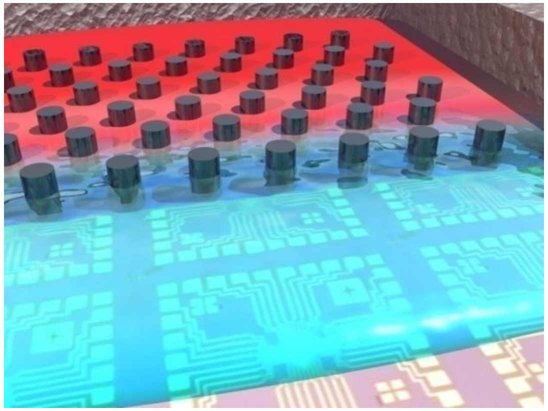
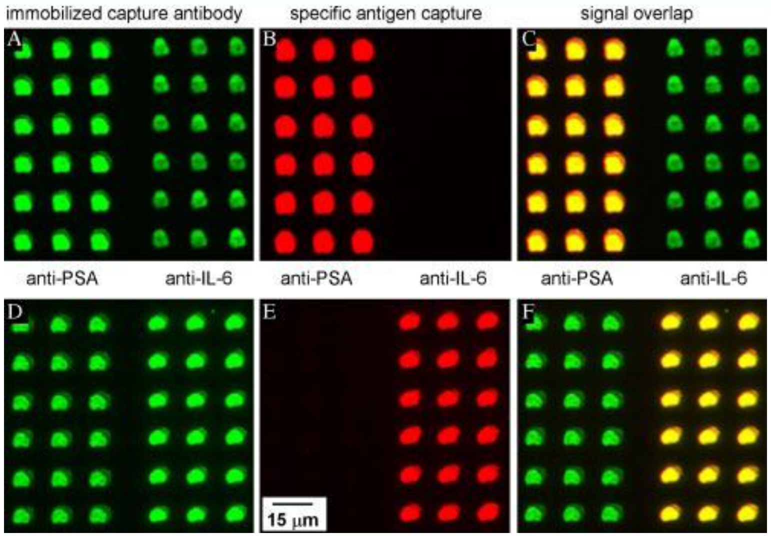
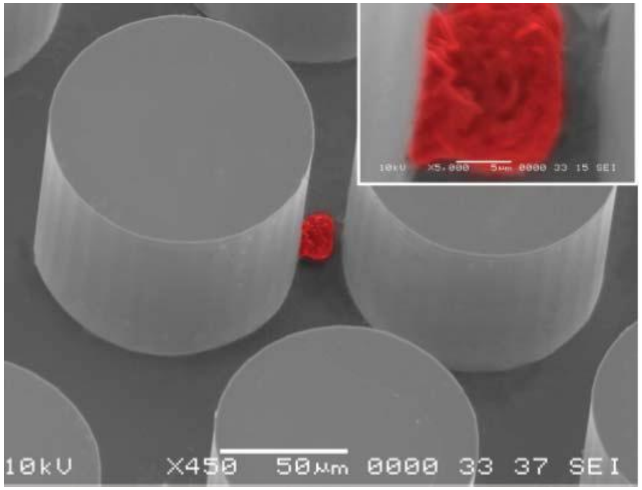


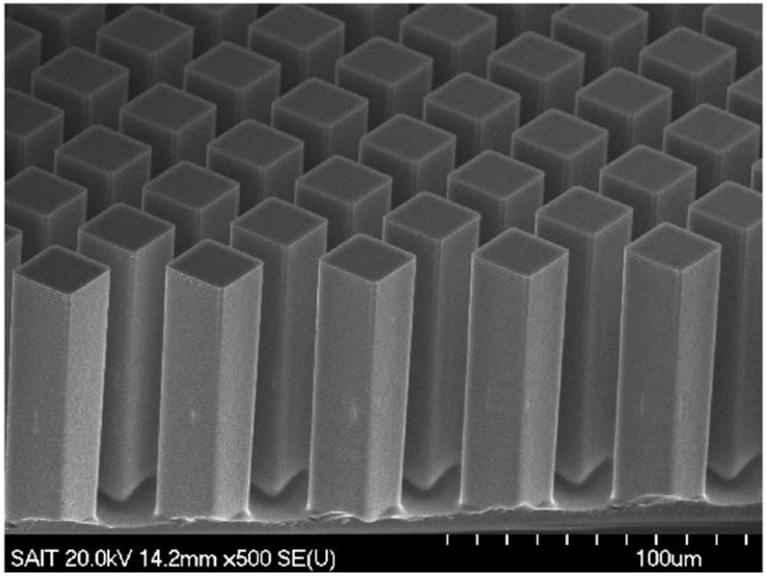


Current applications of pillar structures

Henderson et. al, 2006

Hwang et. al, 2011





Toner et. al, 2007, Nature

MPC Micro Purification Chip

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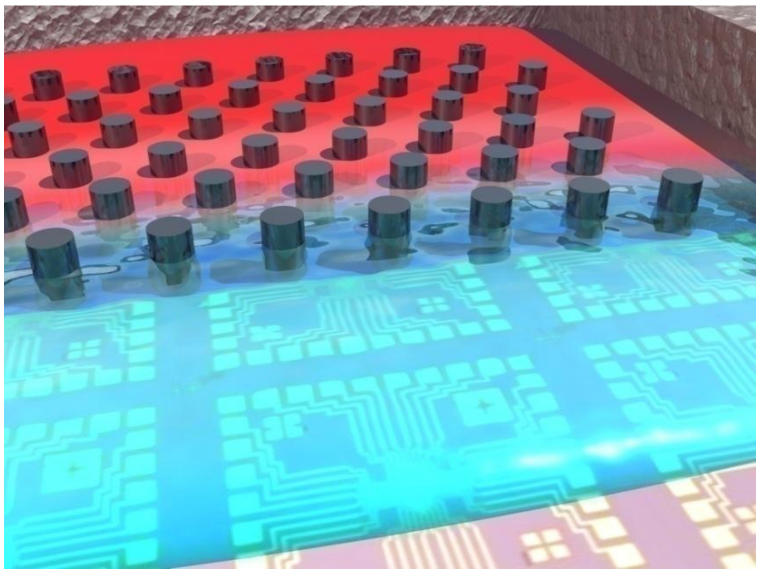
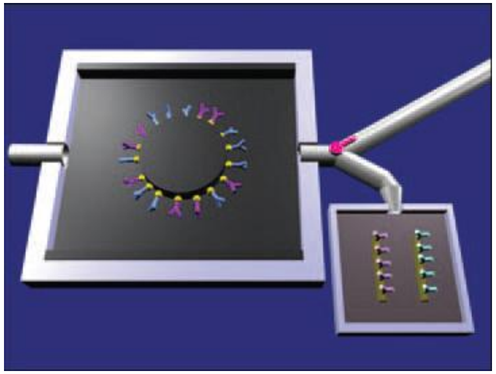
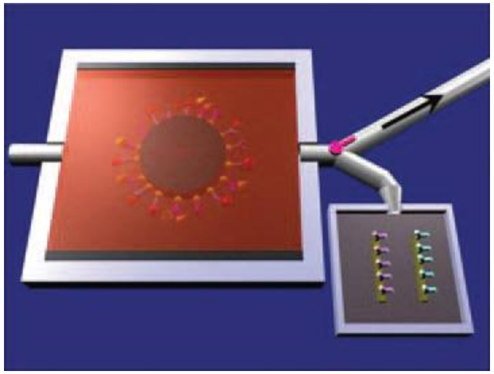


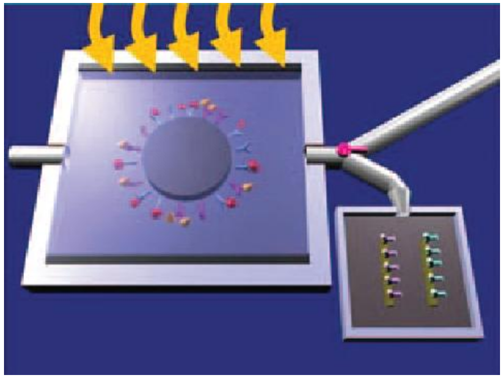
Array of pillars



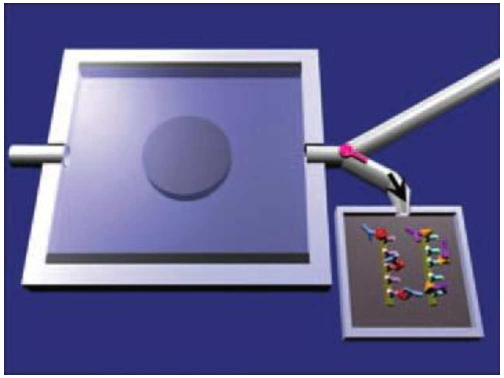
Functionalize C-R region
with antibodies



Blood introduction
protein absorption



Wash with buffer
UV cleave and release



Transfer to NWs
with 2nd antibodies

Micro Purification Chips

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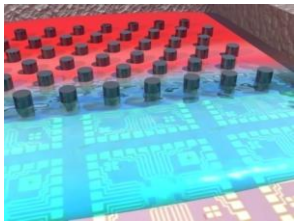
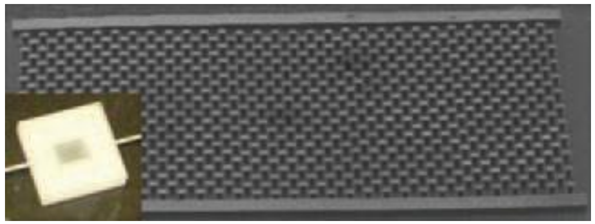


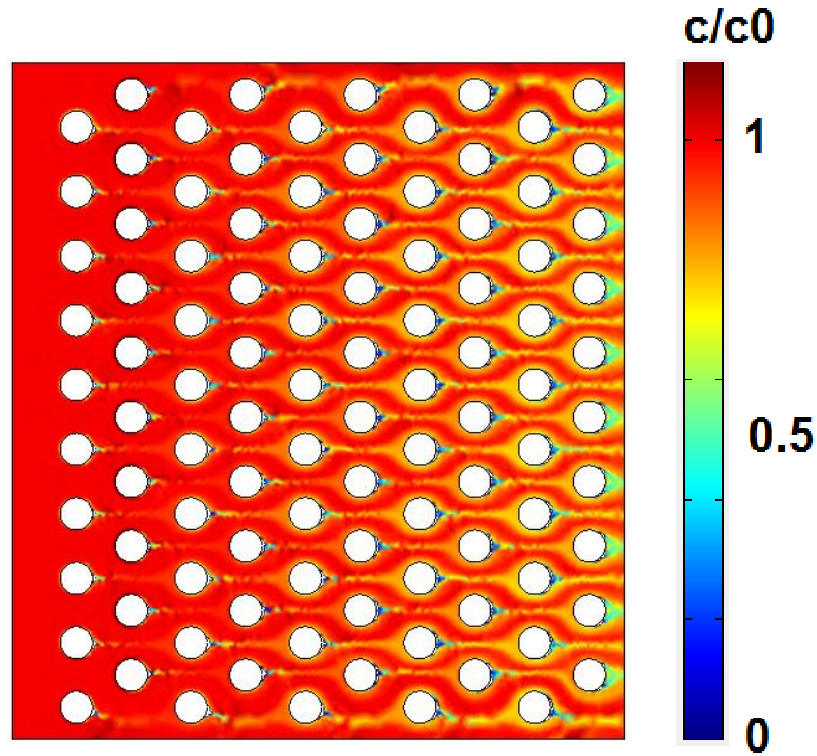


Stern et. al, 2010

MPC have shown **experimental** **10%** capture efficiency

Lets consider a microchannel with 100um pillars, injected liquid with c0 =50 nM ~ 1.6ng/mL PSA concentration at flow rate Q~20nL/min very slow

The **simulated** PSA concentration after passing MPC is 45nM, which shows **10%** capture efficiency



Computational Methods

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vin

c0

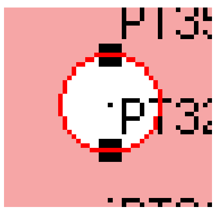
p0

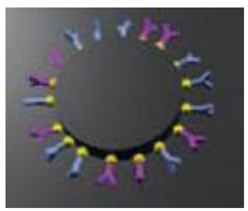
conv flux

MPC Geometry

Microfluidic channel

with Array of functionalized micro-pillars





microchannel
100um x 50um x 10um
Micro-pillar with capture sites

Mathematical Model

- Reaction at NW surface
- Convection & diff.
- Mass balance
- Navier-Stokes equation
- BC @ t=0 – instantaneous fluid injection

$$c + \theta \underset{k_{des}}{\overset{k_{ads}}{\Leftrightarrow}} c_s$$

$$\frac{\partial c}{\partial t} + \nabla \cdot (-D \nabla c + c\mathbf{u}) = 0$$

$$\frac{\partial c_s}{\partial t} + \nabla \cdot (-D_s \nabla c_s) = k_{ads} c(\theta_0 - c_s) - k_{des} c_s$$

$$\rho \frac{\partial \mathbf{u}}{\partial t} - \nabla \cdot \eta(\nabla \mathbf{u} + (\nabla \mathbf{u})^T) + \rho \mathbf{u} \cdot \nabla \mathbf{u} + \nabla p = 0$$

$$c = c_0 \qquad \nabla \cdot \mathbf{u} = 0 \qquad c_s = 0$$

Efficiency for varied structure size

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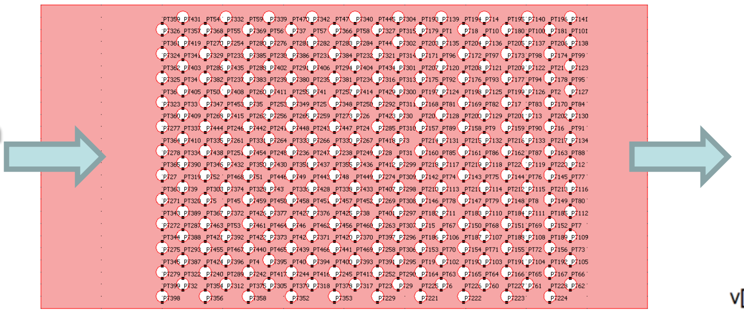
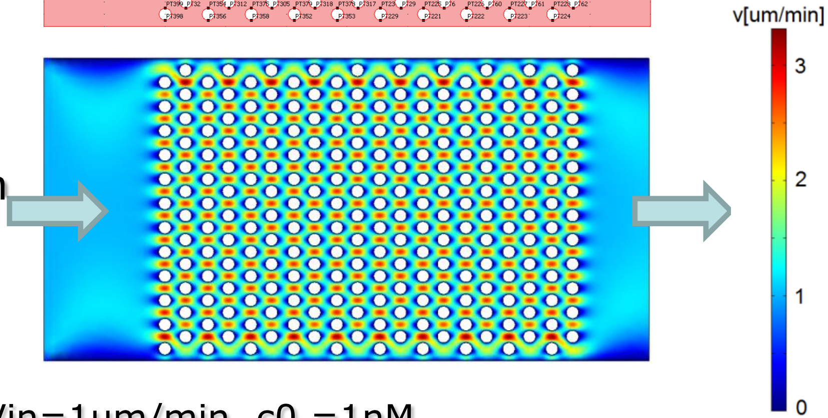
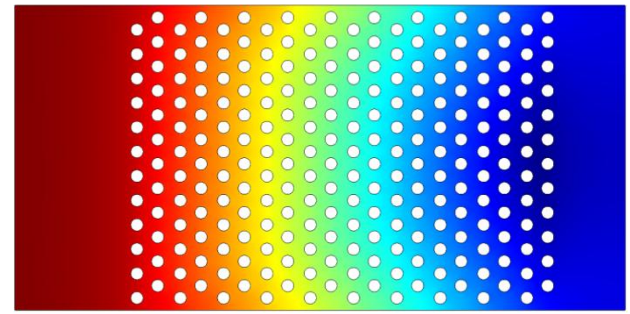
Capture of same initial analyte concentration
with varied pillar size



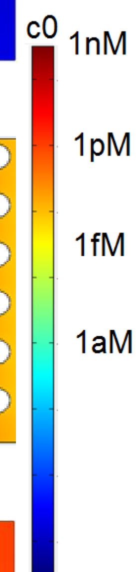


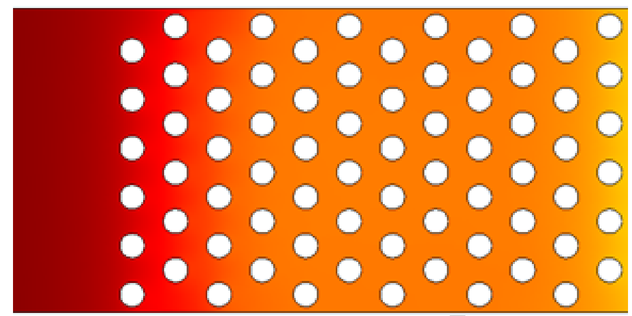
Vin=1um/min, c0 =1nM,
Clinical PSA range
140nM – 1uM

Capture efficiency
c0/cout

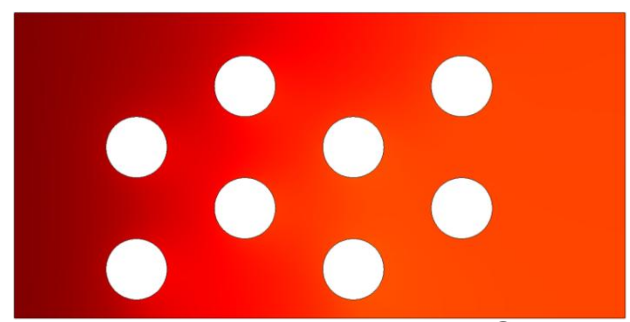


Pillar: 2um; Effic. ~10^{13}





Pillar: 4um; Effic. ~10^{5}



Pillar: 10um; Effic. ~10^{3}

Efficiency for varied concentration

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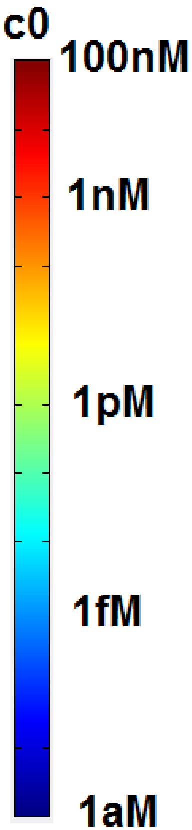
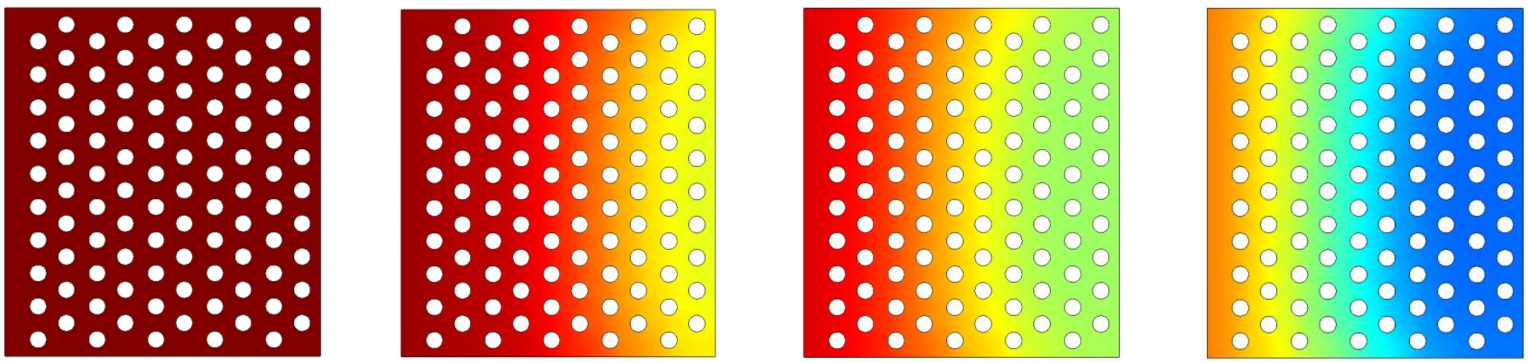
Capture on 2um pillars in the same microchannel geometry
with varied initial analyte concentration





$c_0 = 1uM$	$c_0 = 50nM$	$c_0 = 10nM$	$c_0 = 1nM$
$N_i = 3 \cdot 10^7$	$N_i = 1.5 \cdot 10^6$	$N_i = 3 \cdot 10^5$	$N_i = 3 \cdot 10^4$
$N_f \sim N_i$	$N_f = 1000$	$N_f = 24$	$N_f = 2$

DIFFUSION dominates
HIGH capture cross section
SMALL pillar size

2um pillars

$Nb = 2.5 \cdot 10^8$

Diffusion 200um
on that scale

Summary and conclusions

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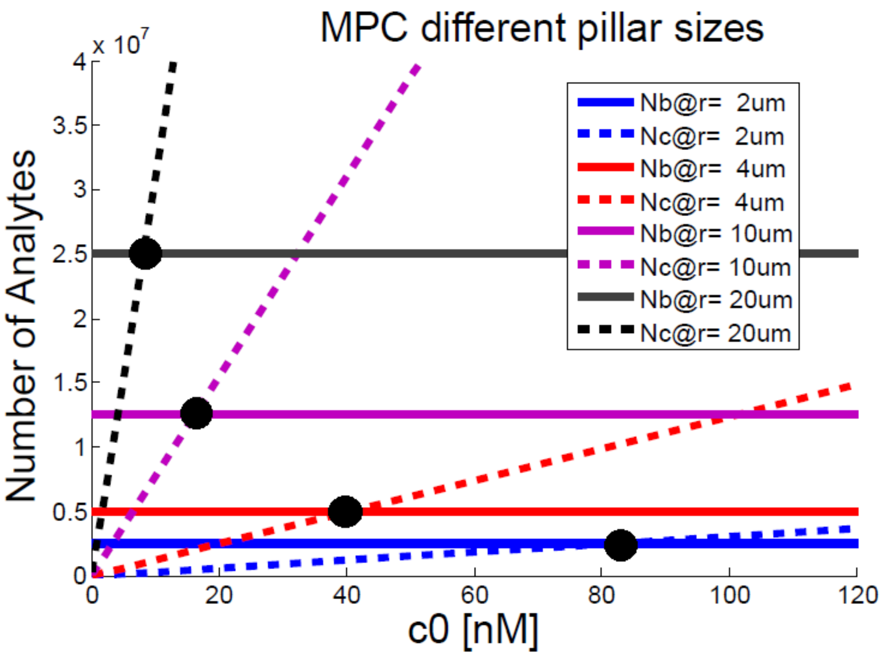
Fill factor 20%

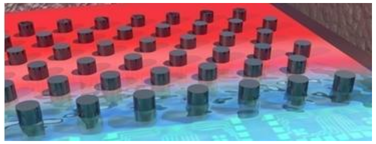


Nb - number of binding sites
Nc – number of analyte molecules

Capture efficiency varies depending on initial analyte concentration and the pillar size.

The efficiency varies from 10% to more than 99.999%.

The choice of Micro-Purification Chip geometry for sample processing has a significant influence on the accuracy of analyte concentration measurements



Size Matters

Thank you

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