2014 Graduate Research Conference
Department of Mechanical Engineering, Iowa State University
March 7, 2014

APTAMER FUNCTIONALIZED MICROCANTILEVER BASED DETECTION OF COCAINE MOLECULES AT ULTRA LOW CONCENTRATION THROUGH COMPETITIVE BINDING

Nazita Taghavi[1*], **Pranav Shrotriya**[2]

Iowa State University of science and technology, Ames, 50011, USA

[1]ntaghavi@iastate.edu

[2]shrotriy@iastate.edu

PhD Program

Introduction

MicroCantilever (MC) based sensors can provide revolutionary sensitivity for forensic detection and identification of controlled substances. We developed a novel "competition" sensing mode based on MC sensors coupled with aptamer-based receptor layers.

In the conventional mode of sensing, surface deformation due to binding of ligand on a surface receptor is measured. In the competition mode, the rate of aptamer dissociation from a surface is measured. The rate of aptamer dissociation is determined by diffusion of the aptamer and its reaction with ligands in solution (Fig.1).

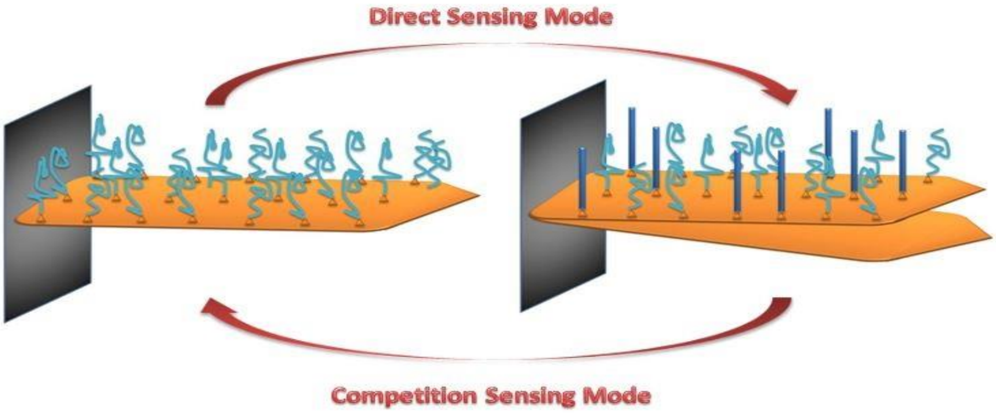

Fig.1 Direct sensing mode and Competition sensing mode

Mathematical Model

In our mathematical model, we assume the microcantilever is a small particle like a spherical cell with radius a and the secretion and unbinding of ligands in the solution can take place in a secretion layer of thickness δ (Fig. 2). The nondimensional form of mathematical equations that governs binding and unbinding of ligands, L^*, with receptors on the surface of the cantilever, R, and receptors in the solution, S^*, using Smoluchowski [1] equation are:

---

*Presenting author: Nazita Taghavi

$$\frac{dR_n}{dt_n} = -A_n L_n^* R_n + C_n \tag{1}$$

$$\frac{dC_n}{dt_n} = A_n L_n^* R_n - C_n \tag{2}$$

$$\begin{aligned}\frac{dL_n^*}{dt_n} = -A_n L_n^* R_n + C_n - K_n A_n L_n^* S_n^* + K_f X_n^* \\ - DL_n L_n^*\end{aligned} \tag{3}$$

$$\begin{aligned}\frac{dS_n^*}{dt_n} = -K_n A_n L_n^* S_n^* + K_f X_n^* \\ - DS_n (SB_n - S_n^*)\end{aligned} \tag{4}$$

$$\frac{dX_n^*}{dt_n} = K_n A_n L_n^* S_n^* - K_f X_n^* - DS_n X_n^* \tag{5}$$

where

$$\begin{aligned}
&R_n = \frac{R}{c_0 A}, && C_n = \frac{C}{c_o A}, \\
&L_n^* = \frac{\delta}{c_0} L^*, && t_n = t \times k_{off} \\
&S_n^* = \frac{\delta}{c_0} S^*, && X_n^* = \frac{\delta}{c_0} X^*, \\
&A_n = \frac{c_0}{\delta k_d}, && DL_n = \frac{4\pi DL(a+\delta)}{A\delta k_{off}}, \\
& && DS_n = \frac{4\pi DS(a+\delta)}{A\delta k_{off}}, \\
&K_n = \frac{k_{on}^s}{k_{on}}, && K_f = \frac{k_{off}^s}{k_{off}}
\end{aligned} \tag{6}$$

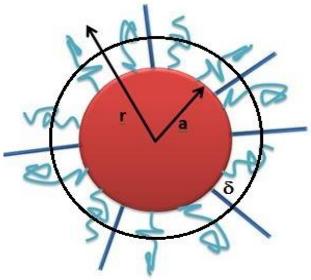

Fig.2 Spherical cell model

The effects of nondimensional parameters such as A_n and DL_n on rate of unbinding of ligands from the cantilever can be investigated by solving the ordinary differential equations, equations (1) to (5).

To see the effects of the concentration of receptors in the solution, we can introduce a measure of diffusion rate, M, as follow:

$$M = \frac{C(t_{n1}) - C(t_{n2})}{C(t_{n1}) + C(t_{n2})} \tag{7}$$

Figures (3) and (4) show the effects of nondimensional parameters A_n and DL_n on measure of diffusion rate for different solution receptors.

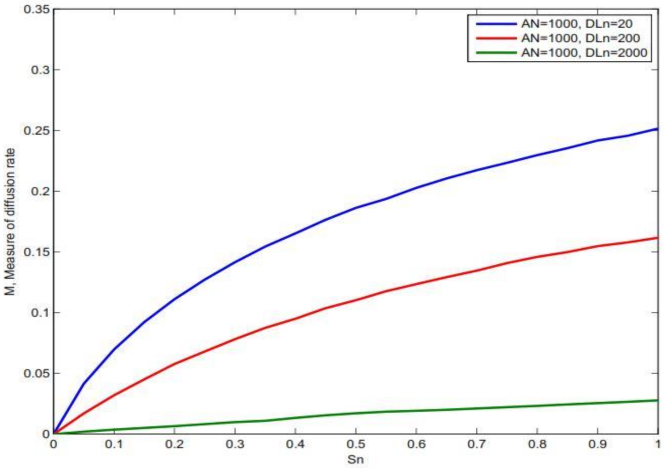

Fig.3 Effect of DL_n on measure of diffusion rate for different solution receptors

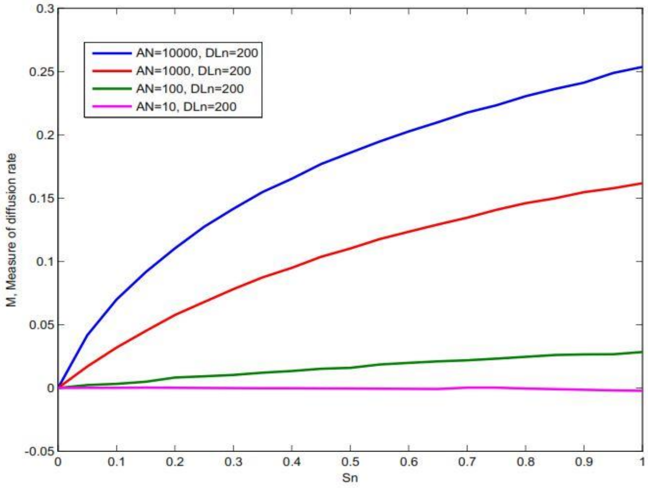

Fig.4 Effect of A_n on measure of diffusion rate for different solution receptors

Reference

[1] Smoluchowski, M. V., 1915, "Versuch einer mathematischen theorie der koagulationskinetik kolloider" *Z. physic, Chem*, 48:1103.