Membrane Solvent Penetration Measurements using Contact Imaging

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Introduction

Contact imaging using silicon fingerprint sensors, originally designed for biometric applications, has shown potential for skin hydration imaging and surface analysis [1-4]. Previous work shows that such sensors are also sensitive to solvents of high dielectric constant, **ε**, which may make them useful for solvent penetration measurements [5]. In this paper, we present our latest study on in-vitro solvent penetration through silicone membranes using contact imaging.

Apparatus

Figure 1 shows the Fujitsu Fingerprint sensor which has 256 x 300 capacitance-sensing pixels, 50μm spatial resolution and 8-bit grayscale resolution.

Figure 1: Fingerprint sensor and solvent penetration through silicone membrane.

Methods

A piece of silicone membrane (thickness ~ 100μm) was cut and placed on the sensor surface, then a small solvent droplet was placed on the top of the membrane (Figure 1). The sensor then recorded images continuously over a period of time. Two solvents were used in this study, water and undiluted alcohol (EtOH). Water has a dielectric constant of 80, whilst EtOH has a dielectric constant of 24.3.

Results and Discussions

Figure 2 shows contact images of water and undiluted alcohol (EtOH) penetrating through the membrane. The results show that water penetrates through the membrane much faster than undiluted alcohol .

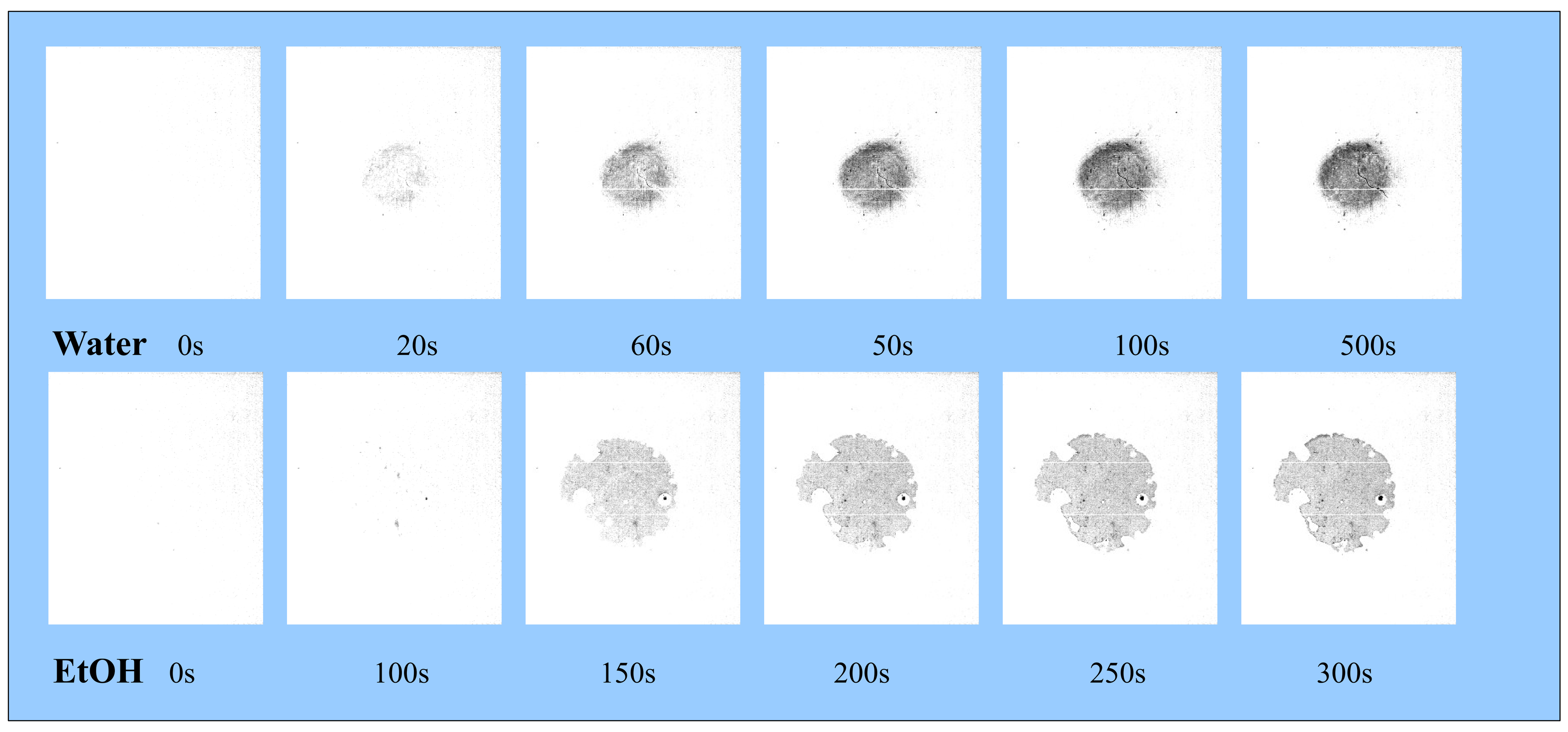

Figure 2. Time-dependent contact images of water and undiluted alcohol penetrating through a silicone membrane.

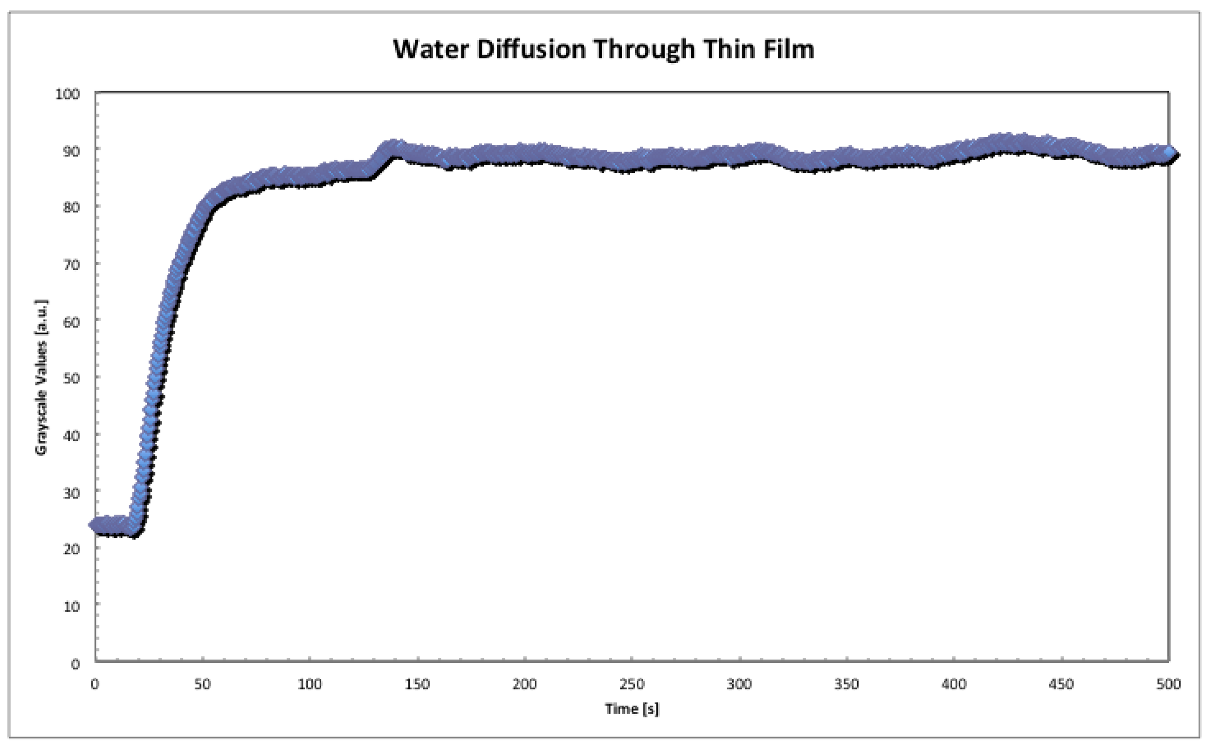

Figure 3. The time dependent grayscale curve during water penetration through the thin film membrane.

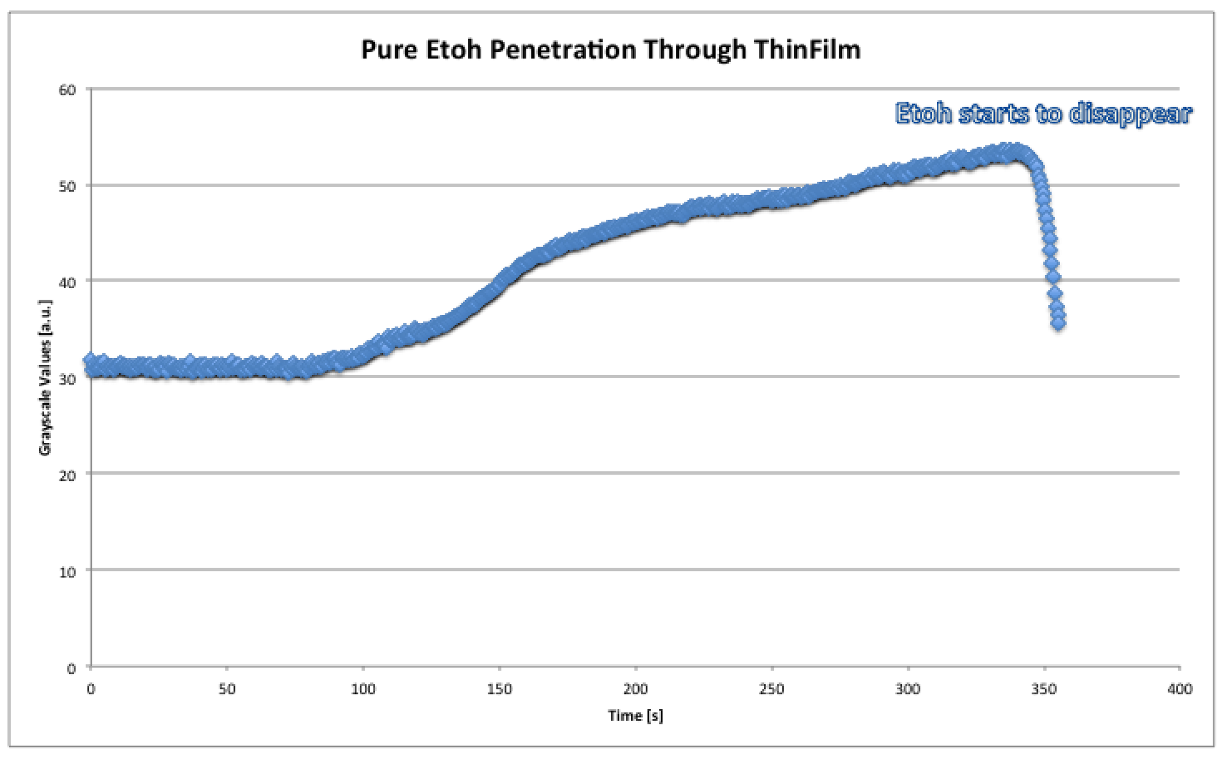

Figure 4. The time dependent grayscale curve during undiluted alcohol penetration through the thin film membrane.

Figure 3 and Figure 4 show the corresponding time dependent grayscale curve corresponding to penetration of water and undiluted alcohol through the silicone membrane. Again, the results confirm that water penetrates through the membrane much faster than undiluted alcohol.

Theoretical Analysis

For solvent penetration through a thin film membrane, a time-lag method was used to analyse the time dependent curve and to determine the permeability and diffusion coefficient of the thin film. If the solvent concentration is assumed to be a constant (C_0) at one side of the membrane, at the surface of the other side of the membrane, the solvent concentration C(t) at time t can be expressed as [6]:

$$\frac{C(t)}{C_0} = 1 - \frac{4}{\pi}\sum_{n=0}^{\infty}\frac{(-1)^n}{2n+1}\exp\left(\frac{-D(2n+1)^2\pi^2 t}{4L^2}\right) \qquad (1)$$

Where D is the diffusion coefficient of the membrane, and L is the thickness of membrane. Using Eq 1 to fit the Figure 3 and 4 data with least squares, it is possible to determine the permeability of the membrane. The diffusion coefficient of the membrane may also be calculated assuming that the thickness of the membrane (L) is 100 um.

Figure 5 show the least squares fitting results for the water penetration data shown in Figure 3. The results show that the diffusion coefficient of the membrane for water is $D = 2.5\times10^{-10}$ m^2 /s and $D/L^2 = 0.025\ s^{-1}$.

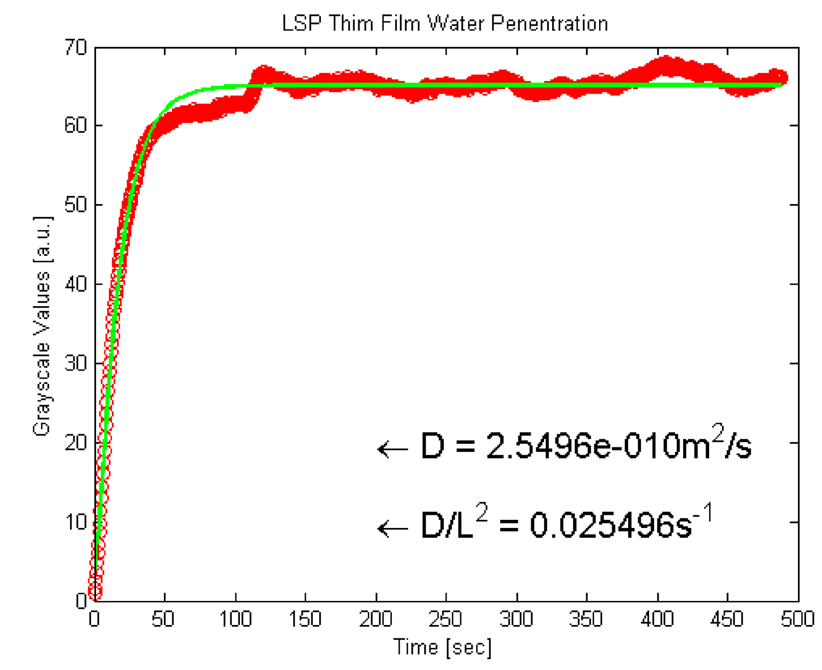

Figure 5. Least Squares Fitted data and experiment data for water penetration.

Figure 6 shows the least squares fitting results for undiluted alcohol penetration data shown in Figure 4. The results show that the diffusion coefficient of the membrane for undiluted alcohol is $D = 3.6\times10^{-11}$ m^2/s and $D/L^2 = 0.0036\ s^{-1}$.

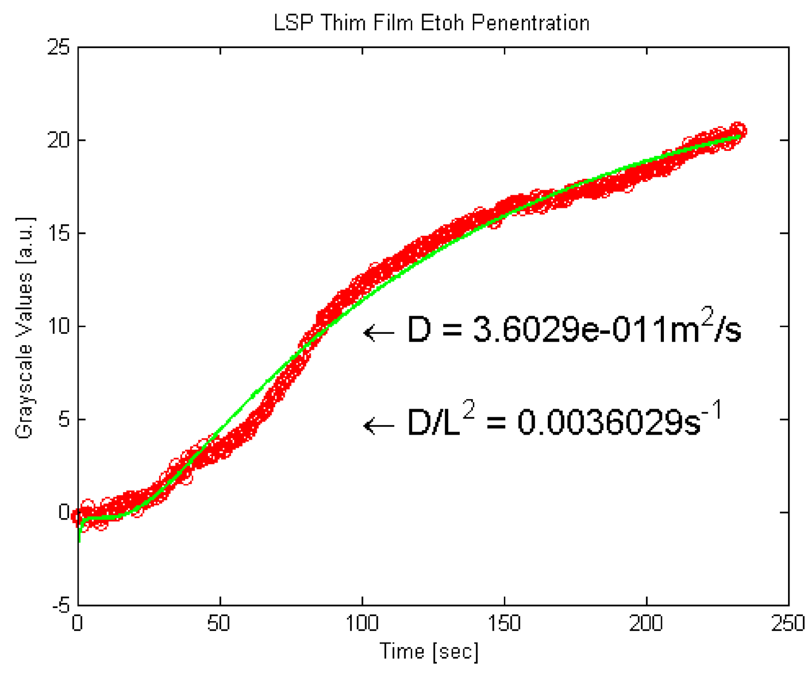

Figure 6. Least Squares Fitted data and experiment data for undiluted alcohol penetration.

Conclusions

The study shows that the capacitance Fingerprint sensor is a powerful tool for studying solvent penetration through membranes. Fingerprint sensors are not only sensitive to water, but also sensitive to solvents with relatively large dielectric constants. By calculating the grayscale values of the images, it is possible to estimate the quantity of solvent that has penetrated through the membrane and from the time-dependence diffusion coefficients may be calculated.. The results have considerable implications for advancing our understanding of excipients in model membranes and ultimately, in skin.

Acknowledgement

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References

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