Capacitive Contact Imaging For Skin Characterization

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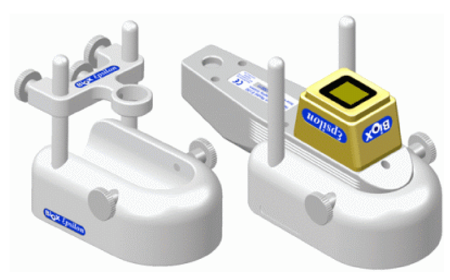
Introduction

Capacitive contact imaging has shown potential in measuring skin properties including skin hydration and skin texture [1-3]. Our previous studies showed it also can be used for solvent penetration measurements [4], skin damage assessments [5], as well as hair and nail water content measurements, despite the low water content [6]. Through calibration we also measure the absolute permittivity of the skin, and from absolute permittivity we then work out the absolute water content (or solvent content) in skin [7]. In this paper, we present our latest study of skin characterization, i.e. dry skin, hydrated skin, sweating, and damaged skin etc., using a commercial contact imaging system, the Epsilon (**Biox Systems Ltd, England**). We will first present the theoretical background and measurement principles, then illustrate the Epsilon calibrations. We will use experimental results to illustrate how the contact images can be used for skin characterization. Through image processing we can focus on the area that we are interested and eliminate the areas that we are not. We will also show latest results on skin solvent penetrations, and how to calculate the absolute solvent content in skin and diffusion coefficient of the solvent.

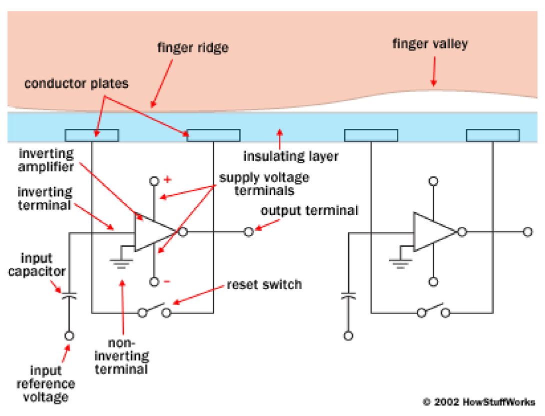
Apparatus

The Epsilon Permittivity Imaging System is based on Fujistu fingerprint sensor (Fujistu Ltd), which has 256x300 pixels with 50μm spatial resolution. Each pixel is equivalent of a capacitive sensor, which measures the dielectric constant or permittivity of the sample, it has a 8-bit grey-scale capacitance resolution per pixel (0 - 255). See **Figure 1**.

A) Epsilon and the in-vivo stand



B) Epsilon and the in-vitro stand



C) Capacitive fingerprint sensor measurement principle [8]

Figure 1: The Epsilon Permittivity Imaging System.

Epsilon Calibration

The Epsilon differs from other such systems in its calibrated, linear response to near-surface dielectric permittivity, see **Figure 2**. The linear response is important because hydration is linearly related to permittivity. The calibration ensures consistency from instrument to instrument and from time to time. With calibrated Epsilon imaging systems we can measure the absolute dielectric permittivity of the material.

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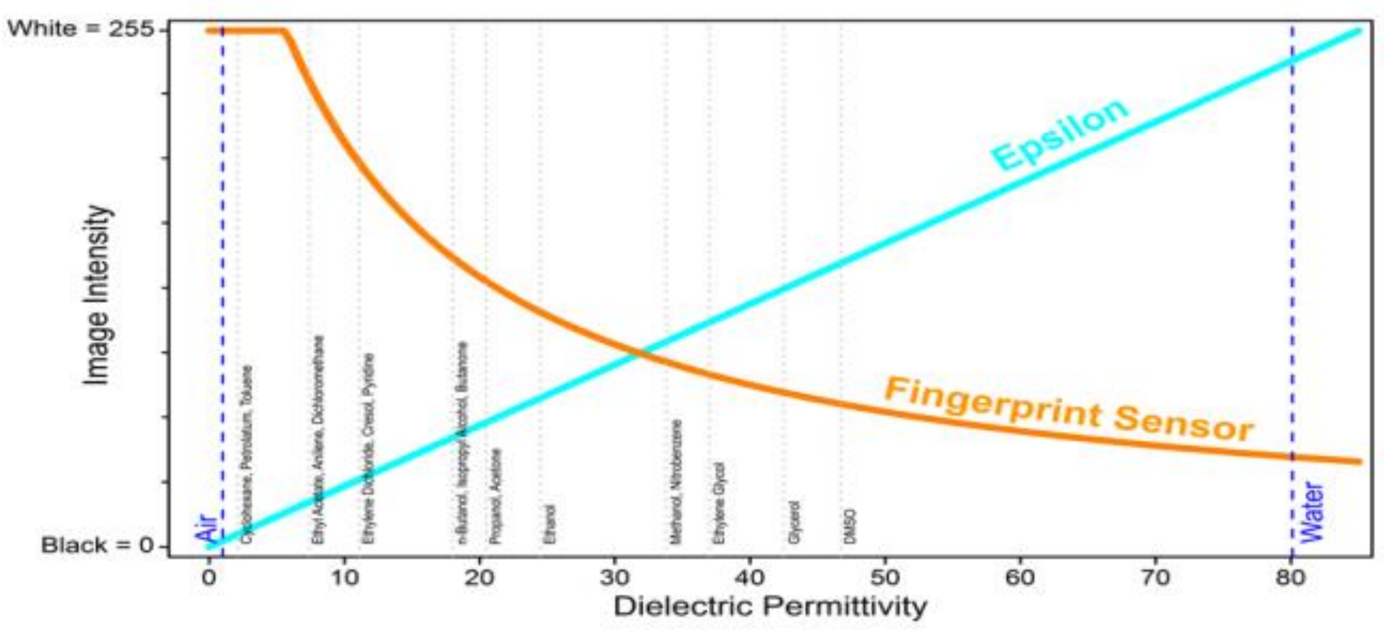
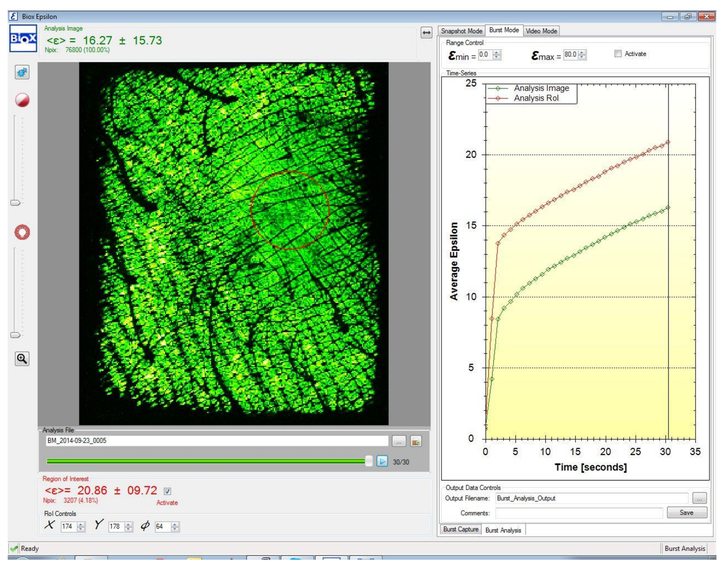


Figure 2. The Epsilon Calibration curve and linear response to dielectric permittivity.

Results and Discussions

Several image processing techniques have been implemented to enhance the measurements. The first is RoI (region of interests) selection. By selecting RoI, we can study the skin area that we are interested, and avoid other interferences such as hair. **Figure 3A** shows the RoI effect in Burst mode, i.e. the sensor is in contact with skin over a period of time, and several images are captured. The time dependent epsilon curves are clearly different in RoI from the whole image. **Figure 3B** show the RoI effect in Snapshot mode, i.e. only one skin image is captured. Again, the histograms of RoI is clearly different from that of the whole image.

A)



B)

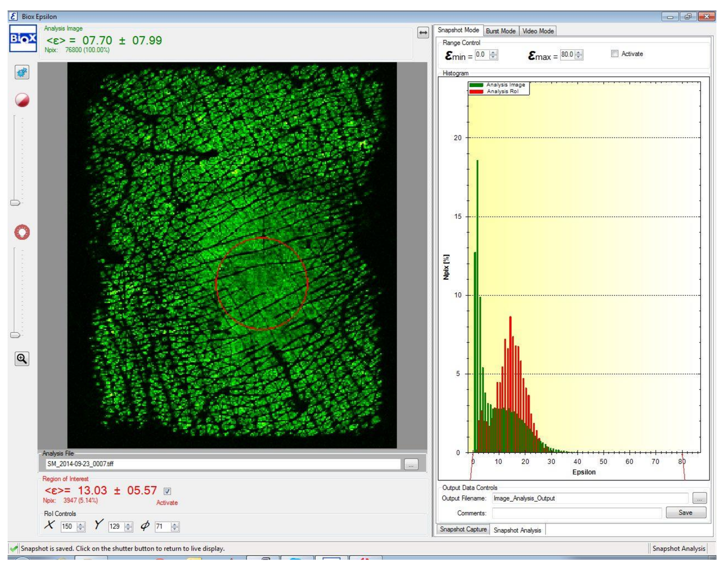
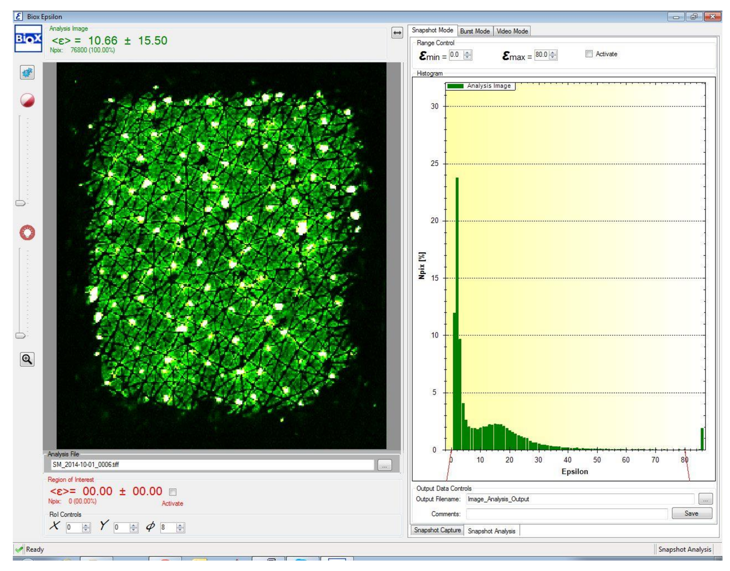


Figure 3: RoI in Burst mode (A) and RoI in Snapshot mode (B).

Another image processing technique is to use upper threshold and lower threshold to eliminate the bad contact area around the edges and sweats, which can improve the results by reducing the standard deviation, as illustrated in **Figure 4**

A)



B)

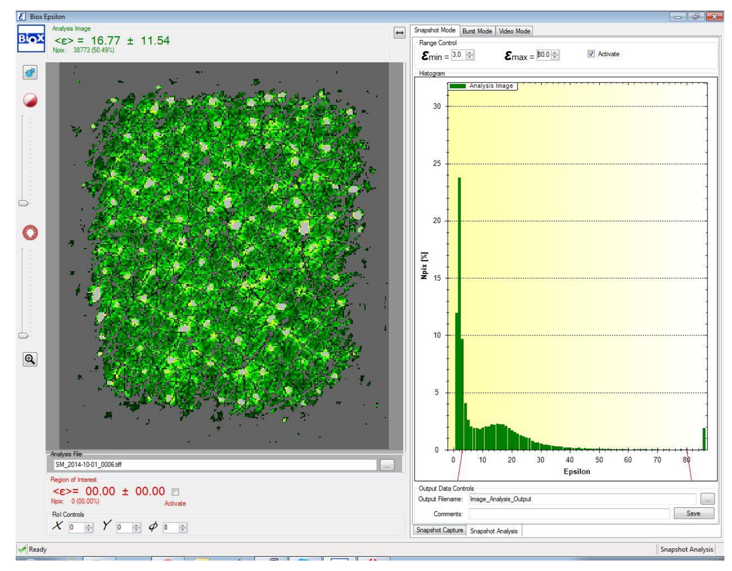
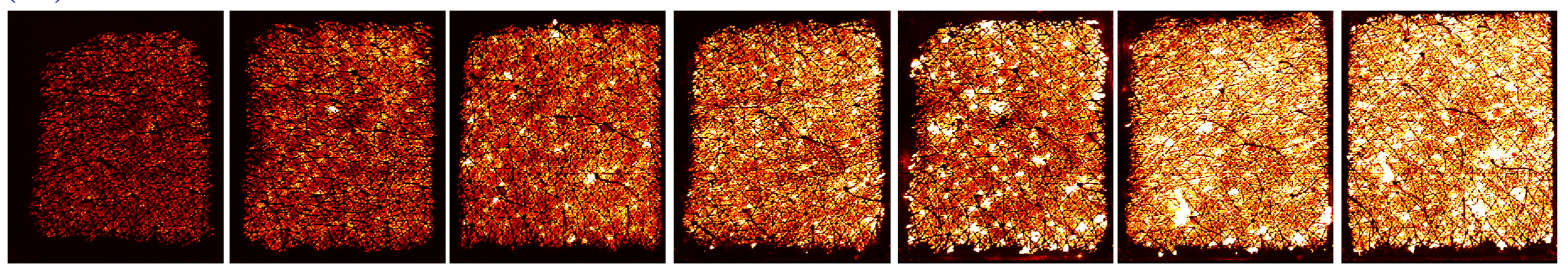


Figure 4: Volar forearm skin image with active sweat gland activities (A) and with upper and lower thresholds to eliminate the bad contact area(grey colour), around the edges and sweats (B).

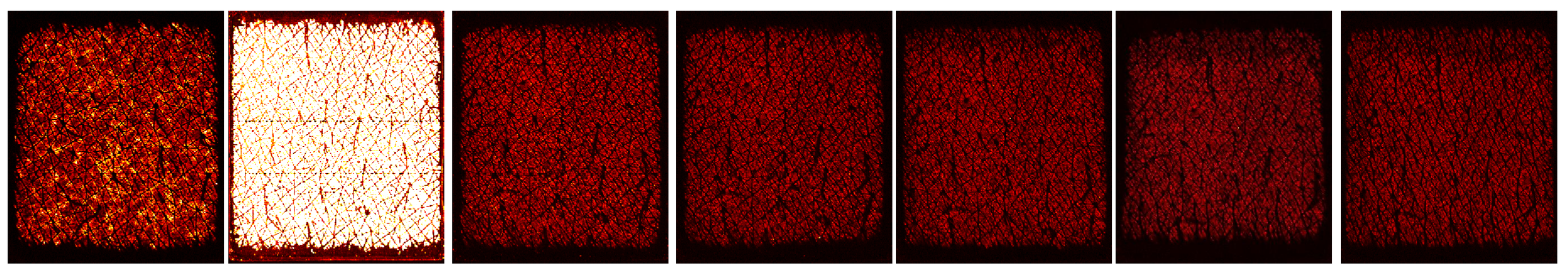
Figure 5 shows the capacitive contact images during tape stripping (top) and SLS (Sodium Lauryl Sulfate, 2% v/v) irritation (bottom). By assuming measured Epsilon value (ε) is linearly dependent on that of dry skin ($\varepsilon_{dryskin}$) and water (ε_{water}), we can work out the water content using following equation [6]:

$$H=(\varepsilon - \varepsilon_{dryskin})/(\varepsilon_{water} - \varepsilon_{dryskin}) \quad (1)$$

Using Eq.(1) we worked out that during tape stripping measurements skin water content has increased from ~10% to ~60% (v/v) after 12 tape strips. While in SLS irritation measurements, skin water content has decreased from initial ~20% down to ~11% (v/v).



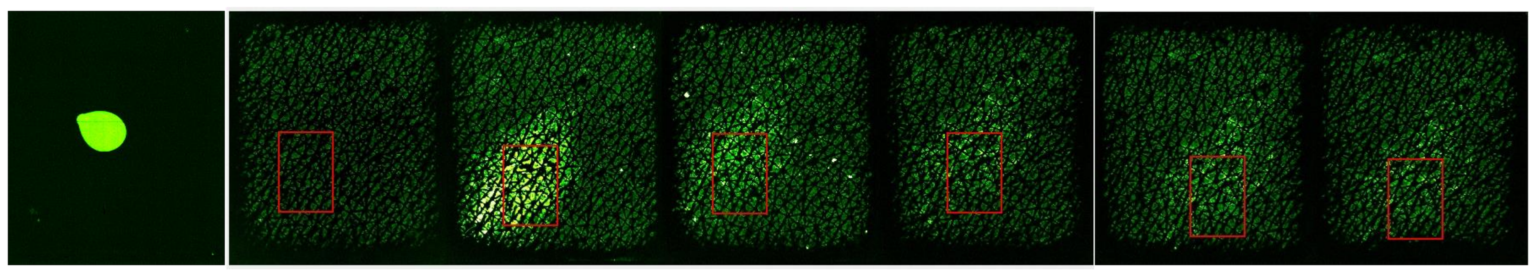
Before | After Tape Stripping(2strips) | 4 strips | 6 strips | 8 strips | 10 strips | 12 strips



Before | After (SLS) | 5 min | 10 min | 15 min | 20 min | 25 min

Figure 5. Capacitive contact images of volar forearm test sites during tape stripping (top), SLS (Sodium Lauryl Sulfate) irritation (bottom).

Figure 6 shows a 5min Glycerol application measurement. Similarly, we can use $C=(\varepsilon - \varepsilon_{skin})/(\varepsilon_{Glycerol} - \varepsilon_{skin})$ to work out the Glycerol concentration. By using re-positioning technique (RoI + cross correlation), we can select exactly the same skin region we want to analyse in each image, see following red squares. The results show that Glycerol in skin has reached to ~38% (v/v) after just 5min Glycerol application. Then as Glycerol gradually diffuse into to skin, the concentration reduced to 16% (20 min), 9% (30min), 10% (40min) and 6% (50 min).



Glycerol | Normal Skin | After 0 min | 20min | 30 min | 40min | 50min

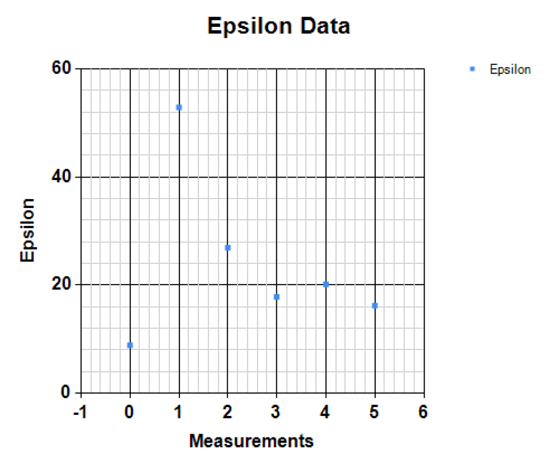


Figure 6. Capacitive contact images of Glycerol application measurement (top). Red squares show the repositioning of the RoI in Normal Skin image and in the consequent images, and corresponding calculated results (bottom).

Conclusions

Capacitive contact imaging can provide useful information for skin characterizations. Through image processing, we can reduce the measurement errors. Through calibration, we can get a linear, absolute, electric permittivity measurement., and through absolute permittivity we can also get absolute water content, as well as solvent concentration in skin. By using re-positioning technique, we can analyse exactly the same skin region in each skin image.

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