The Epsilon is a novel instrument for imaging dielectric permittivity ($\varepsilon$) of a wide variety of soft materials, including animal and plant tissues, waxes, fats, gels, liquids and powders. Its proprietary electronics and signal processing transform the sensor's native non-linear signals into a calibrated permittivity scale for imaging properties such as hydration or recording dynamic processes such as textile wetting or the permeation of liquids through membranes.

- Capacitance measurement principle
- Calibrated for dielectric permittivity $\varepsilon$
- Measurement range from air ($\varepsilon=1$) to water ($\varepsilon=80$)
- Spring-loaded sensor for consistent contact force
- 50µm image resolution, ~20µm depth resolution
- Sensing area 12.8 x 15mm
- Proprietary software for image capture and analysis
- Compatible with Windows Vista/7/8
The Epsilon uniquely offers a contact imaging capability that is calibrated and responds linearly to near-surface dielectric permittivity $\varepsilon$. This is illustrated schematically by the light blue line in the figure below.

The vertical axis shows image intensity, which spans the 8-bit range 0-255. The horizontal axis shows dielectric permittivity, which spans the range between air ($\varepsilon=1$) and water ($\varepsilon=80$). Also shown along the horizontal axis are the permittivities of common liquids, as examples to illustrate how the Epsilon would respond.

The native response of a typical fingerprint sensor is variable and non-linear, illustrated by the orange line in the above figure. At low permittivities, the readings can be off-scale, producing an image of maximum intensity (255, white). This is done in order to display a uniform image background, even when the sensor surface is dirty. At high permittivities, the response is non-linear, with progressively decreasing sensitivity. This causes fingerprint lines to be imaged with a consistent dark grey colour for a wide range of skin hydration values. Therefore, fingerprint sensors are good for fingerprinting, but less than good for quantitative imaging.

Linearisation of the native fingerprint sensor response is achieved by (i) altering the operating characteristics of the readout electronics to keep sensor readings on-scale for the entire range of permittivities of interest and (ii) mapping the resultant signals onto a linear scale by means of a mathematical model of the sensor’s characteristics. The calibration data and other settings are stored on a flash drive located inside the Epsilon instrument and connected to the computer through the same USB connection as the image sensor.

After calibration there is a direct proportionality between permittivity and displayed image intensity, with a constant of proportionality of 3. This provides an optimal mapping of permittivity onto the 8-bit (0-255) intensity scale used for displaying and saving images, up to a maximum permittivity of $\varepsilon=85$.

Another reason why calibration is important is sensor response variability. Calibration ensures consistent measurements from instrument to instrument and from time to time.

Snapshot image of the outside (left) and inside (right) surfaces of a sample of pig skin used to measure solvent penetration dynamics and heterogeneity.
EPSILON MODEL E100

The Epsilon is a novel contact-imaging system for capturing dielectric permittivity ($\varepsilon$) images of insulating materials in contact with its CMOS array sensor surface. The system consists of a hand-held probe, a parking base and an in-vitro stand, securely stored in a purpose-designed case. The system is quick and easy to set up, needing nothing more than a USB connection to a PC or laptop for power and data.

HAND-HELD PROBE

The probe handle is machined from a tough, solvent-resistant plastic. The sensor head is engineered to resist chemical attack. The sensor is spring-mounted to apply a controlled contact force to the samples under test.

PARKING STAND

The parking stand incorporates an electrically conducting receptacle that acts as a Faraday cage to protect the sensor from static electricity.

IN-VITRO STAND

The in-vitro stand provides a firm base for mounting the probe with its sensor surface horizontal and facing upwards. This enables isolated soft solids and liquids to be studied. It has two vertical posts for mounting a height-adjustable holder for measurement accessories.

IN-VITRO ACCESSORIES

Standard accessories include hollow donor chambers of 5mm and 8mm internal diameter and a solid pressure plug for studying in-vitro solid materials such as leaves. These slip into the mounting ring of the accessories holder and are retained by the central Nylon thumb screw. There is also a matching lid to minimise evaporation of volatile solvents from the donor chambers.

Use the donor chambers for studies of solvent permeation through membranes. Such measurements can complement conventional Franz cell measurements by characterising membrane heterogeneity. You can also measure permeabilities from videos of the time-course of such experiments. Select different regions of interest to compare diffusion rates at different sites.

CASE

The Epsilon comes in a sturdy case, securely packed in anti-static foam. The case also contains an instruction manual, software memory stick and some consumables for sensor cleaning.
SOFTWARE

The software has facilities for snapshot, burst and video-mode image capture, aided by live image and graphical displays. In all capture modes an Event Trigger can be used to delay the start of capture until contact is made with the sensor surface. Images and videos are saved using industry-standard formats. Sensitivity can be enhanced by user-controlled multi-image averaging.

Shown on the right is a screenshot of a live display in snapshot capture mode. The upper graph shows a time-series of average permittivity for the whole image (red) and the Region of Interest (green). The lower graph shows histograms of the respective permittivity distributions.

Recorded images can be analysed using the Range Control to mask low and high permittivity pixels. Video recordings can be similarly analysed, but with the added facility to track frame to frame changes. The software also has a powerful facility to display a reference image or video alongside the image of interest, as illustrated in the screenshot on the right. In this case, permittivities below 2.0 (dark grey) and above 38.0 (light grey) have been masked out. The remaining pixels give a better measure of hydration, for example, because contributions from areas of poor contact (low permittivities) and surface water at sweat gland openings (high permittivities) are excluded.

Analysis results are saved in Excel-compatible tsv (tab-separated values) files for further analysis and display.

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APPENDIX:

BIBLIOGRAPHY OF SCIENTIFIC RESEARCH USING CAPACITIVE CMOS ARRAY SENSORS

1. L’ORÉAL PATENTS

Method of acquiring an image of a non-dermatoglyphic zone of the skin or of a zone of the hair by means of acquisition apparatus including a non-optical sensor.


Apparatus and method to evaluate hydration of the skin or the mucous membranes.


NB: Some methods described in the publications listed here are subjects of these patents.

2. JOURNAL & BOOK PUBLICATIONS

SkinChip, a new tool for investigating the skin surface in vivo.


From skin microrelief to wrinkles: an area ripe for investigations.


What is SkinChip? From silicon image sensor technology to SkinChip.


Influence of age on the lips and perioral skin.


Silicon image sensor technology for in vivo detection of surfactant-induced corneocyte swelling and drying.


Capacitance imaging of the skin surface.


Skin capacitance imaging and corneousurfametry. A comparative assessment of the impact of surfactants on stratum corneum.


Skin capacitance imaging, a new technique for investigating the skin surface.


Skin capacitance imaging for dermatologists.


Contrasted skin capacitance imaging of seborrheic keratoses and melanocytic nevi.


Highlighting the rim of the perifollicular epidermal unit.


Skin capacitance mapping of psoriasis.


Skin capacitance imaging of acne lesions.


Comparative study of the hydration of the stratum corneum between four ethnic groups: influence of age.


Unexpected distribution of surface hydration level of the lip.


Skin capacitance imaging.


Photoaging of the chest analyzed by capacitance imaging.


The skin landscape following nonoptical capacitance imaging.


Characterization of the skin using capacitance imaging.


Facing up to the imperceptible perspiration. Modulatory influences by biological neuropathy, physical exercise and antiperspirant.


Ustekinumab biotherapy and real-time psoriasis capacitance mapping: a pilot study.


3. CONFERENCE PRESENTATIONS

Age-related skin analysis by capacitance images.

Bevilacqua A, Gherardi A. Proc 17th Intl Conf Pattern Recogn (ICPR'04).

Capacitance imaging: new parameters for characterizing the skin surface texture, effect of hydration. (Abstract)


Images de la peau in-vivo par capteurs d’empreintes digitales.


In-vivo solvent penetration measurement using contact imaging and skin stripping.


Skin Integrity Testing and Monitoring of In-vitro Tape Stripping by Capacitance-based Sensor Imaging.