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**From:** [REDACTED] [REDACTED] <[REDACTED]>  
**Sent:** Tuesday, August 16, 2011 7:31 PM  
**To:** Jeffrey [REDACTED]  
**Subject:** RE: Epidermal Electronics and Electronic Second Skin

Can't do today plus Boris back tomorrow will be able to get his assessment too...will be back in touch tomorrow !

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From: Jeffrey Epstein  
Sent: Tuesday, August 16, 2011 12:28 PM  
To: [REDACTED] [REDACTED]  
Subject: Re: Epidermal Electronics and Electronic Second Skin

[REDACTED]

On Tue, Aug 16, 2011 at 9:26 PM, [REDACTED] [REDACTED] <[REDACTED]>  
<mailto:[REDACTED]> > wrote:

Offline...

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From: Jeffrey Epstein  
Sent: Tuesday, August 16, 2011 12:00 PM  
To: [REDACTED] [REDACTED]  
Subject: Re: FW: Epidermal Electronics and Electronic Second Skin

what will happen , vs balmer.?

2011/8/16 [REDACTED] [REDACTED] <[REDACTED]>  
<mailto:[REDACTED]> > >

steve is great.  
:-)

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From: Jeffrey Epstein [jeevacation@gmail.com <mailto:jeevacation@gmail.com> ]  
Sent: Tuesday, August 16, 2011 2:03 AM  
To: [REDACTED] [REDACTED]  
Subject: Re: FW: Epidermal Electronics and Electronic Second Skin

I read it and loved the idea..... how is it going with steve

2011/8/16 [REDACTED] <[REDACTED]>  
<mailto:[REDACTED]> >>

From: [REDACTED]  
Sent: Monday, August 15, 2011 9:06 PM  
To: Bill Gates ([REDACTED] <mailto:[REDACTED]> )  
Cc: Boris Nikolic (BGC3) ([REDACTED] <mailto:[REDACTED]> ); Lowell  
Wood ([REDACTED] <mailto:[REDACTED]> )  
Subject: Epidermal Electronics and Electronic Second Skin  
Importance: Low

Pretty neat – I’m not sure if you’ve seen this.

There are a couple of areas where further development is needed...RF communication frequencies change when the circuits are stretched, and dead skin and sweat have to be dealt with during long-term use. These aren’t insurmountable complications, though.

Am attaching two related papers. Both from Science today. One describes in more detail the “electronic second skin” and the other about “epidermal electronics.”

The authors acknowledge medical applications but they seem most interested in making this into game controllers. :)

Temporary tattoos fitted with electronics make flexible, ultrathin sensors

By Kyle Niemeyer <<http://arstechnica.com/author/kyle-niemeyer/>>

Modern methods of measuring the body's activity, such as electroencephalography (EEG), electrocardiography (ECG), and electromyography (EMG), use electrical signals to measure changes in brain, heart, and muscle activity, respectively. Unfortunately, they rely on bulky and uncomfortable electrodes that are mounted using adhesive tape and conductive gel—or even needles. Because of this, these types of measurements are limited to research and hospital settings and typically used over short periods of time because the contacts can irritate skin.

These limitations may be at an end, however. New research published in Science describes technology that allows electrical measurements (and other measurements, such as temperature and strain) using ultra-thin polymers with embedded circuit elements. These devices connect to skin without adhesives, are practically unnoticeable, and can even be attached via temporary tattoo.

All of the necessary components of the devices, including electrodes, electronic components, sensors, radio frequency communication components, and power supplies, are set within an extremely thin (about 30  $\mu\text{m}$ ) elastic polyester sheet. The sheet has a low elastic modulus (that is, it's flexible) and no noticeable mass (about 0.09 g), so you have a lightweight, stretchable membrane.

Circuit elements (such as transistors, diodes, resistors) and sensors are constructed with typical materials like silicon and gallium arsenide, but are linked using nanoribbon and micro/nanomembrane elements to allow extremely small but flexible designs.

The authors refer to their approach as an "epidermal electronic system" (EES), which is basically a fancy way of saying that the device matches the physical properties of the skin (such as stiffness), and its thickness matches that of skin features (wrinkles, creases, etc.). In fact, it adheres to skin only using van der Waals forces—the forces of attraction between atoms and molecules—so no adhesive material is required. Between the flexibility and the lack of adhesive, you wouldn't really notice one of these attached.

One of the coolest aspects of this technology is the application method: temporary (transfer) tattoo. Yes, the ones you used as a kid, where you hold the transfer sheet with the design onto your skin then dampen it to dissolve the sheet. Here, they used water-soluble polyvinyl alcohol (PVA) sheets in the same manner.

For a power supply, initial designs used silicon photovoltaic cells to generate electricity, but these are limited to microwatts due to the small area. Researchers also explored wireless inductive power, where an external transmission coil matches the resonance frequency of a small inductive coil in the device (it's the same sort of tech that's used in wireless device chargers). This opens up the door for applications that need more power than solar can provide, or for devices that work in low-light conditions (under clothing, for example). The authors also suggest future electrical storage using capacitors or batteries.

As demonstrations, the authors used their devices to measure heartbeats on the chest (ECG), muscle contractions in the leg (EMG), and alpha waves through the forehead (EEG). The results were all high quality, comparing well against traditional electrode/conductive gel measurements in the same locations. In addition, the devices continuously captured data for six hours, and the devices could be worn for a full 24 hours without any degradation or skin irritation.

One interesting demonstration that also suggests future applications was the measuring of throat muscle activity during speech. Different words showed distinctive signals, and a computer analysis enabled the authors to recognize the vocabulary being used.

The team even hooked one of these sensors up to a simple computer game (Sokoban <<http://en.wikipedia.org/wiki/Sokoban>> ) and used throat activity as the controller. Identifying each word took about three seconds using a MATLAB program, but it had a higher than 90 percent accuracy. While the potential videogame applications are endless, you can also think of other areas, such as silent communications or better voice recognition software.



[REDACTED]

[REDACTED]

[REDACTED]

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