Integrating Chemo/Bio-sensing Capabilities into Wearable Platforms

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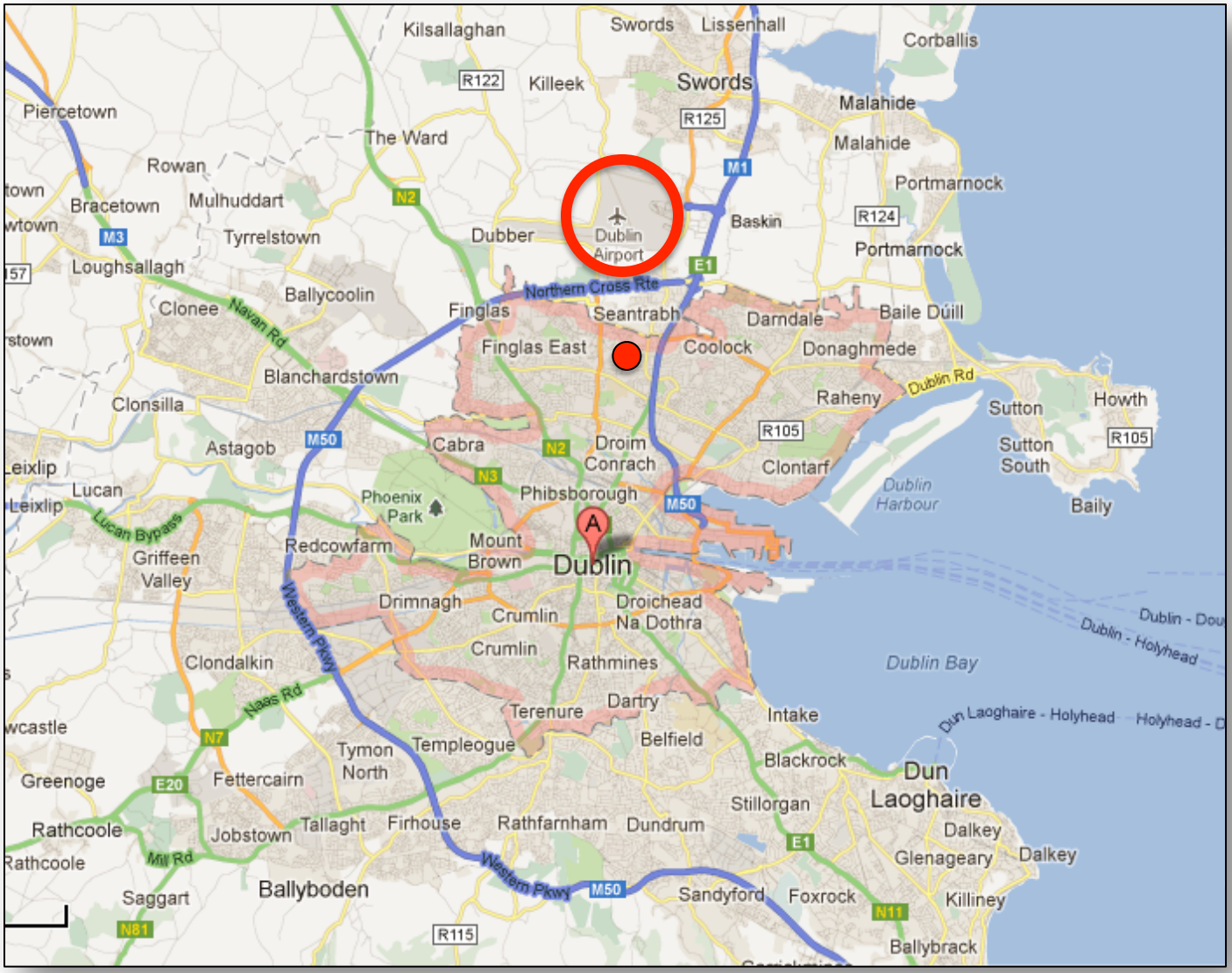
Dublin City University

presented at

GE-NBMC Workshop 'Wearable Electronics Technology & Applications in Health & Human Performance'

General Electric, Niskayuna, New York, 23rd May 2014

Dublin & DCU Location



National Centre for Sensor Research (NCSR)

- Over 220 f/t researchers and support staff
- 23 affiliated faculty
- Research investments and income since 1999 now >€100 million
- 1500 m^2 well-equipped specialist lab space and offices
- Phase II expansion completed 2008 (1300 m^2)
- NCSR is a 'Hosting Centre' – supports externally funded initiatives

CLARITY
clarity-centre.org

Insight
The Centre for Sensor Web Technologies

BAS
Centre for BioAnalytical Sciences

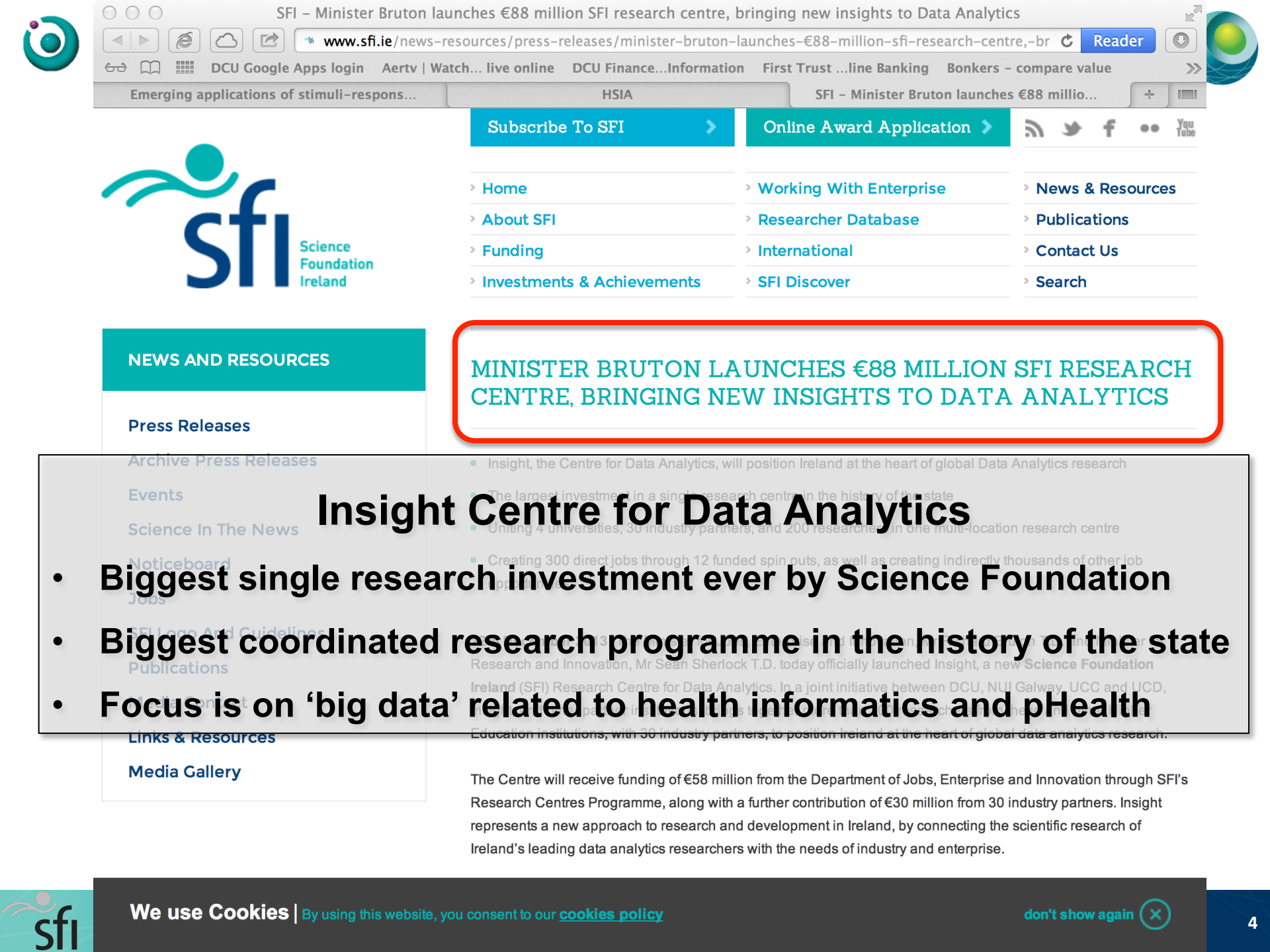
bdi
biomedical diagnostics institute

Marine Institute
Foras na Mara

epa
Environmental Protection Agency

Beaufort, SmartCoast, SmartBay, Strive

sfi DCU UCC OÉ Gaillimh NUI Galway UCD DUBLIN

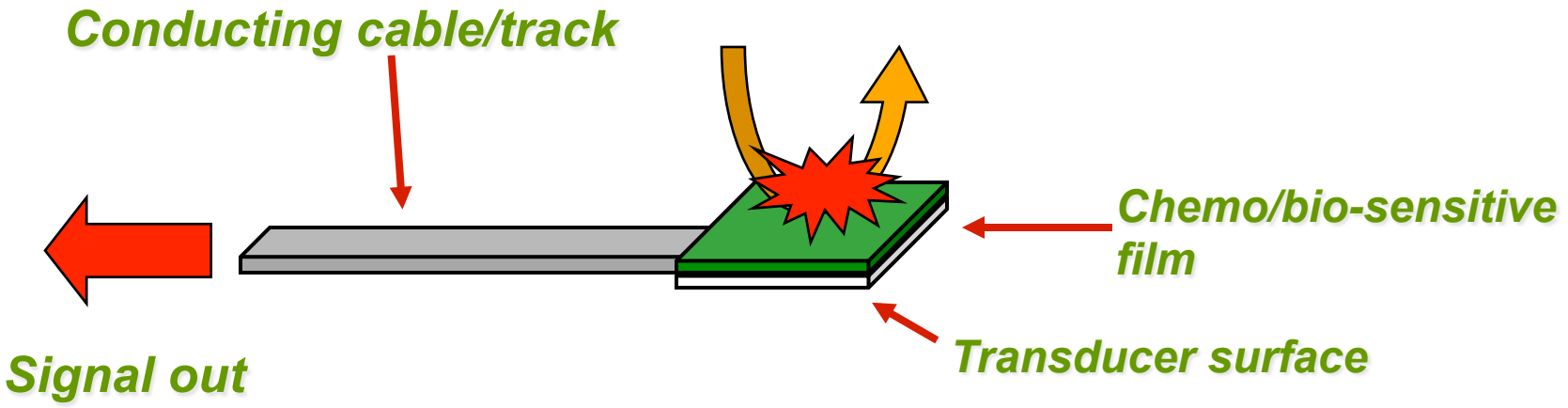


Insight Centre for Data Analytics

- **Biggest single research investment ever by Science Foundation**
- **Biggest coordinated research programme in the history of the state**
- **Focus is on 'big data' related to health informatics and pHealth**

What is a Chemo/Bio-Sensor?

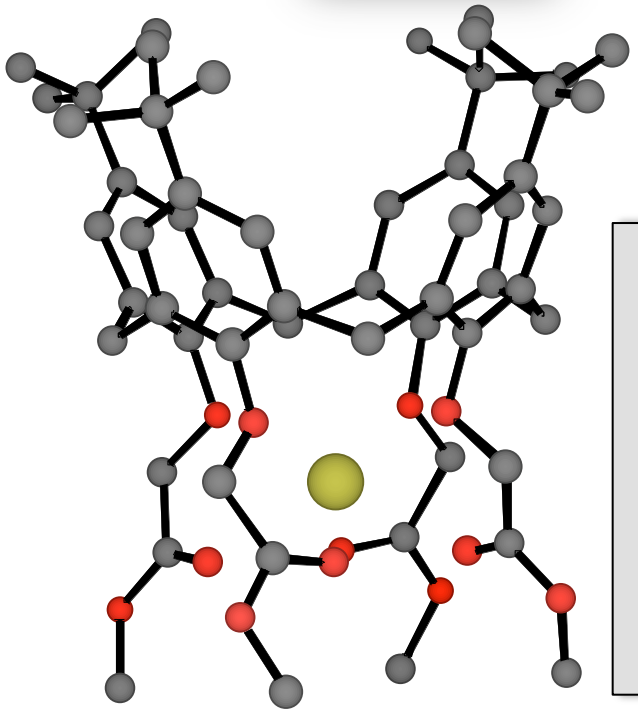
'a device, consisting of a transducer and a chemo/bio-sensitive film/membrane, that generates a signal related to the concentration of particular target analyte in a given sample'

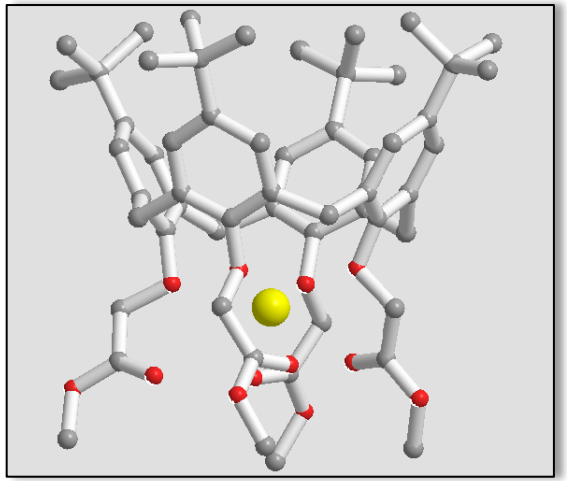


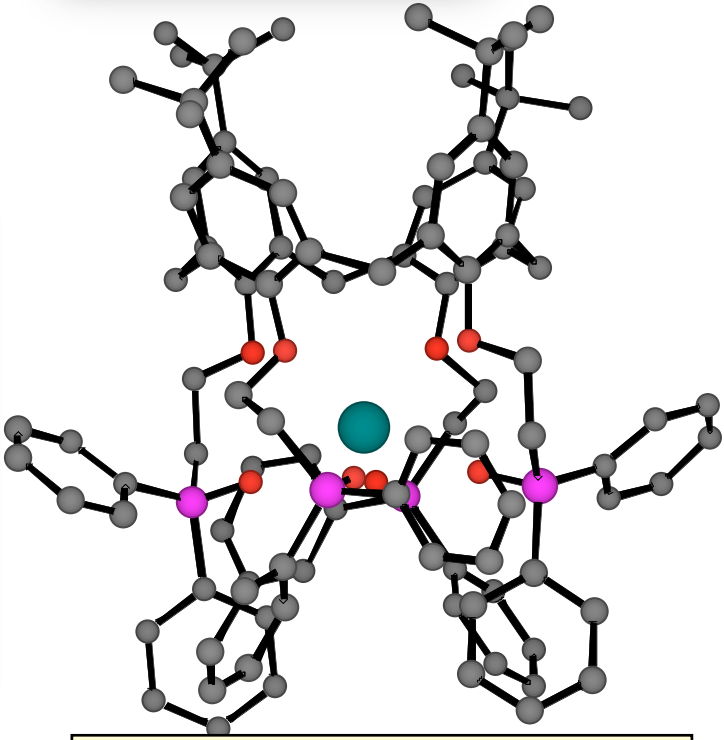
Chemo/Bio-sensing involves selective **BINDING** & **TRANSDUCTION** on the device surface; this also implies the target analyte MUST meet the device surface (**LOCATION** & **MOVEMENT**). It provides a signal observable in the macroscopic world (**COMMUNICATION**)

History: Calixarenes, 1984/5

+



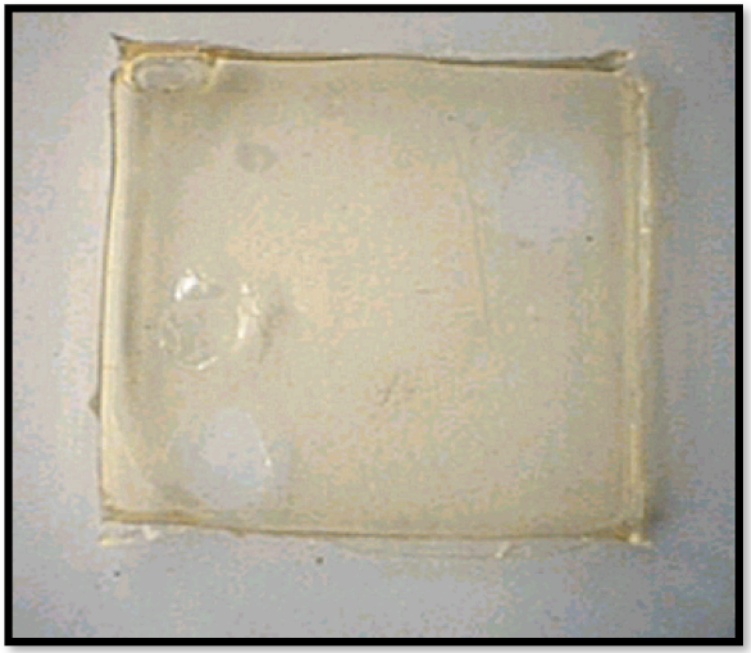


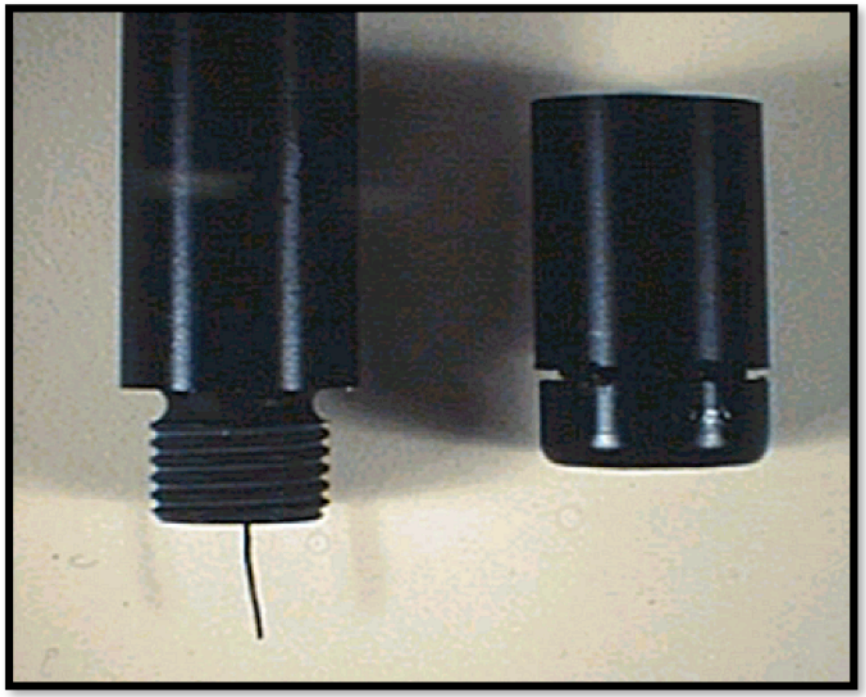


Tetraester - Na+ selective

Tetraphosphine oxide - Ca^{2+} selective

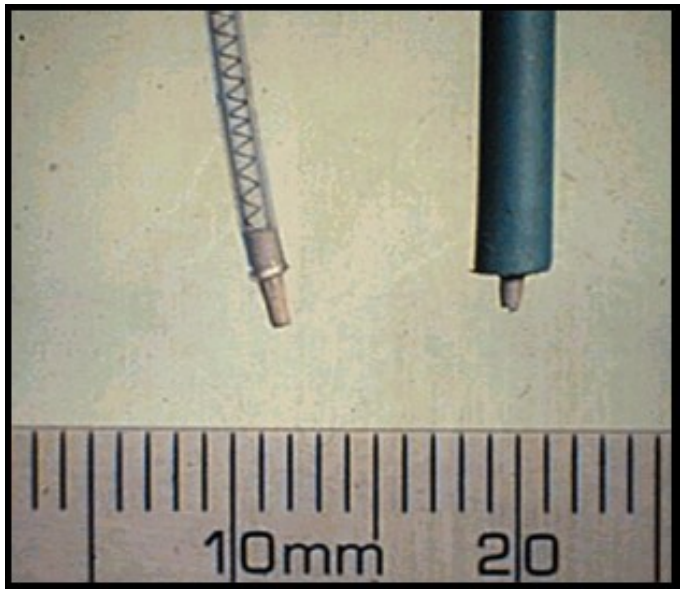
PVC - Membrane ISEs





Typical membrane cocktail (%w/w); PVC:33%, NPOE (plasticiser):66%; ionophore/exchanger: 1% (ratio at least 2:1 by mole); dissolve in a volatile solvent e.g. THF and cast membrane from this solution

Blood Analysis; In-Vo Sensing



1985: Catheter Electrodes for intensive care – function for 24 hr

Dr. David Band, St Thomas's Hospital London

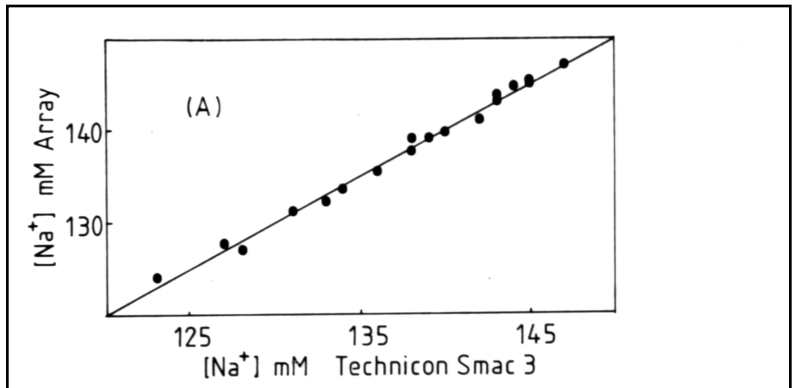
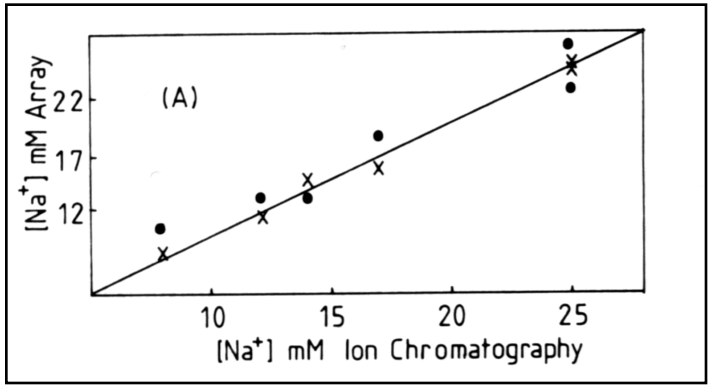


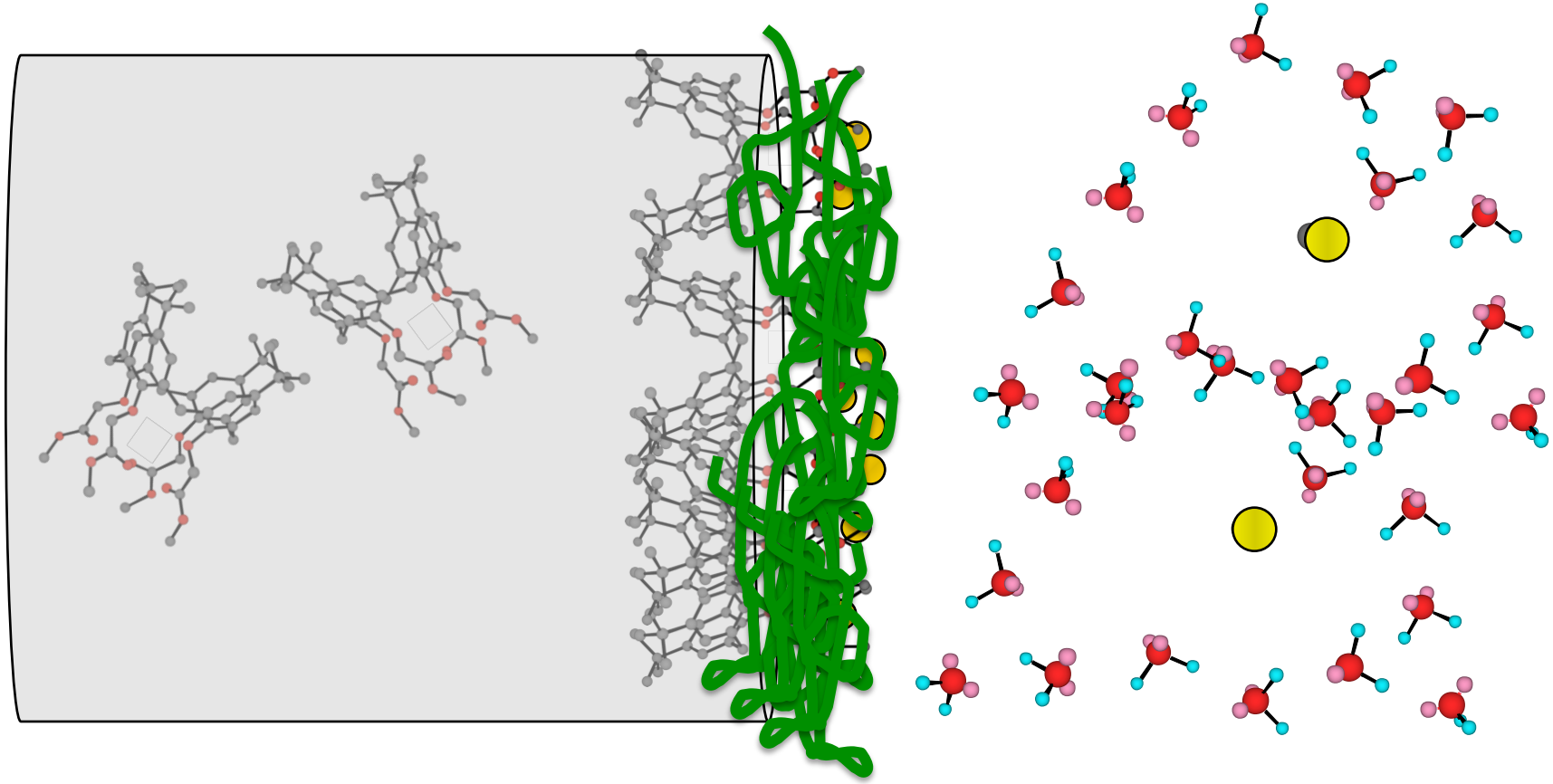
Fig. 3. Comparison of plasma sodium analysis using the array-FIA approach with a SMAC analyser. Good correlation without bias is obtained [5].



Anal. Chem., *64 (1992) 1721-1728.*

Ligand (and variations of) used in many clinical analysers for blood Na^+ profiling

Control of membrane interfacial exchange & binding processes



Remote, autonomous chemical sensing is a tricky business!

Implantable sensors e.g. The Artificial Pancreas….

- Implantable unit comprising a glucose sensor (based on enzyme glucose oxidase) coupled with insulin reservoir
- Effective lifetime – many years (5-yr minimum target)
- Problem: glucose biosensor will not function reliably for more than a few days when implanted
- How to remotely calibrate
- Stability of reagents/calibrants

But the concept of the artificial pancreas has been around for decades;
SUGAR ELECTRODE SENSOR FOR ARTIFICIAL PANCREAS
By: BESSMAN, SP; SCHULTZ, RD
HORMONE AND METABOLIC RESEARCH Volume: 4 Issue: 6 Pages: 413-417 Published: 1972

Artificial Pancreas

A. M. ALBISSER, M.A.SC., PH.D., AND ASSOCIA

Used a Technicon segmented flow colorimetric glucose analyser

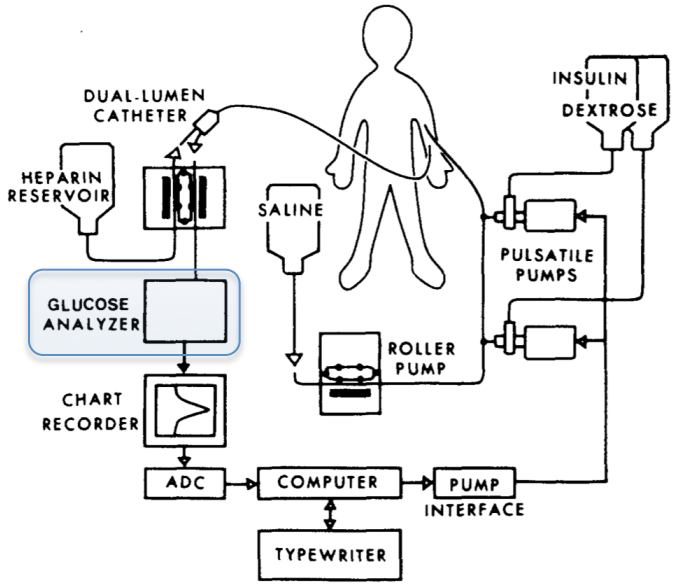
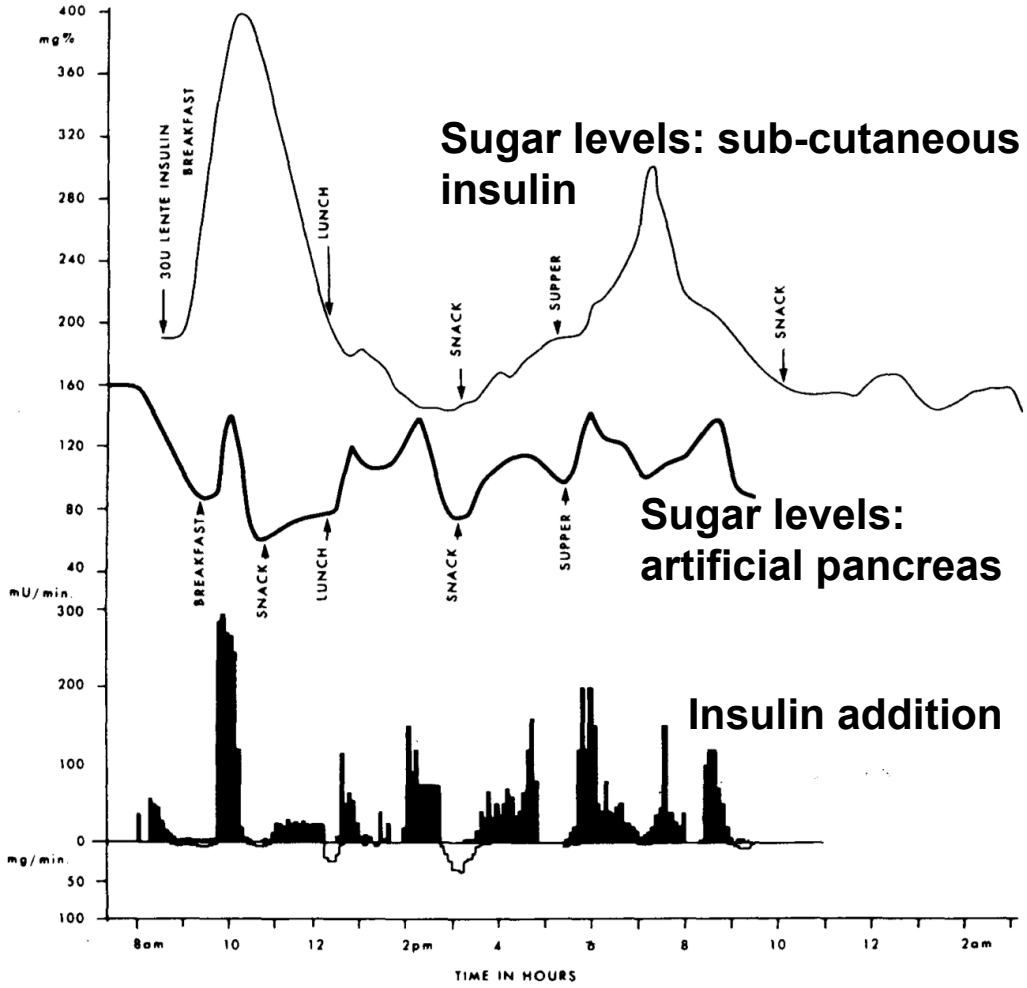
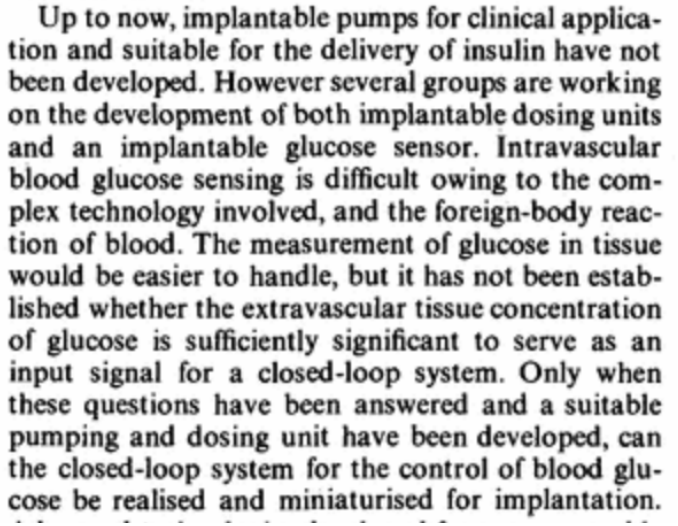


FIG. 1. Schematic diagram of apparatus used for monitoring and automatic regulation of blood sugar.



A M Albisser, B S Leibel, T G Ewart, Z Davidovac, C K Botz, W Zingg, H Schipper, and R Gander
Clinical Control of Diabetes by the Artificial Pancreas
Diabetes May 1974 23:5 397-404; doi:10.2337/diab.23.5.397 1939-327X (Toronto)

Impantable Artificial Pancreas



Up to now, implantable pumps for clinical application and suitable for the delivery of insulin have not been developed. However several groups are working on the development of both implantable dosing units and an implantable glucose sensor. Intravascular blood glucose sensing is difficult owing to the complex technology involved, and the foreign-body reaction of blood. The measurement of glucose in tissue would be easier to handle, but it has not been established whether the extravascular tissue concentration of glucose is sufficiently significant to serve as an input signal for a closed-loop system. Only when these questions have been answered and a suitable pumping and dosing unit have been developed, can the closed-loop system for the control of blood glucose be realised and miniaturised for implantation.

An implantable artificial pancreas, W. Schubert, P. Baurschmidt, J. Nagel, R. Thull, M. Schaldach;

Medical and Biological Engineering and Computing, July 1980, Volume 18, Issue 4, pp 527-537

'Intravascular blood glucose sensing is difficult **owing to the complex technology involved** and **the foreign body reaction of blood**.'

'The measurement of glucose **in tissue would be easier to handle**, but it has not been established whether the **extravascular tissue concentration of glucose is sufficiently significant to serve as an input signal for a closed-loop system**'

Adam Heller

Subcutaneous sampling of interstitial fluid using microneedles to access the fluid through the skin without causing bleeding

San Francisco Business Times; Tuesday, April 6, 2004

'Abbott completes TheraSense acquisition'

Abbott Laboratories said Tuesday it completed its $1.2 billion acquisition of Alameda-based TheraSense Inc. after a majority of shareholders approved the transaction a day earlier.

- **Abbott Press Release September 29, 2008**
- Abbott Park, Illinois — Adam Heller, Ph.D., a professor at the University of Texas in Austin who created the technology that led to the development of Abbott's FreeStyle Blood Glucose Monitoring Systems® and FreeStyle Navigator® Continuous Glucose Monitoring System, today received the 2007 National Medal of Technology and Innovation from President George W. Bush in an award ceremony at the White House.

Freestyle Navigator

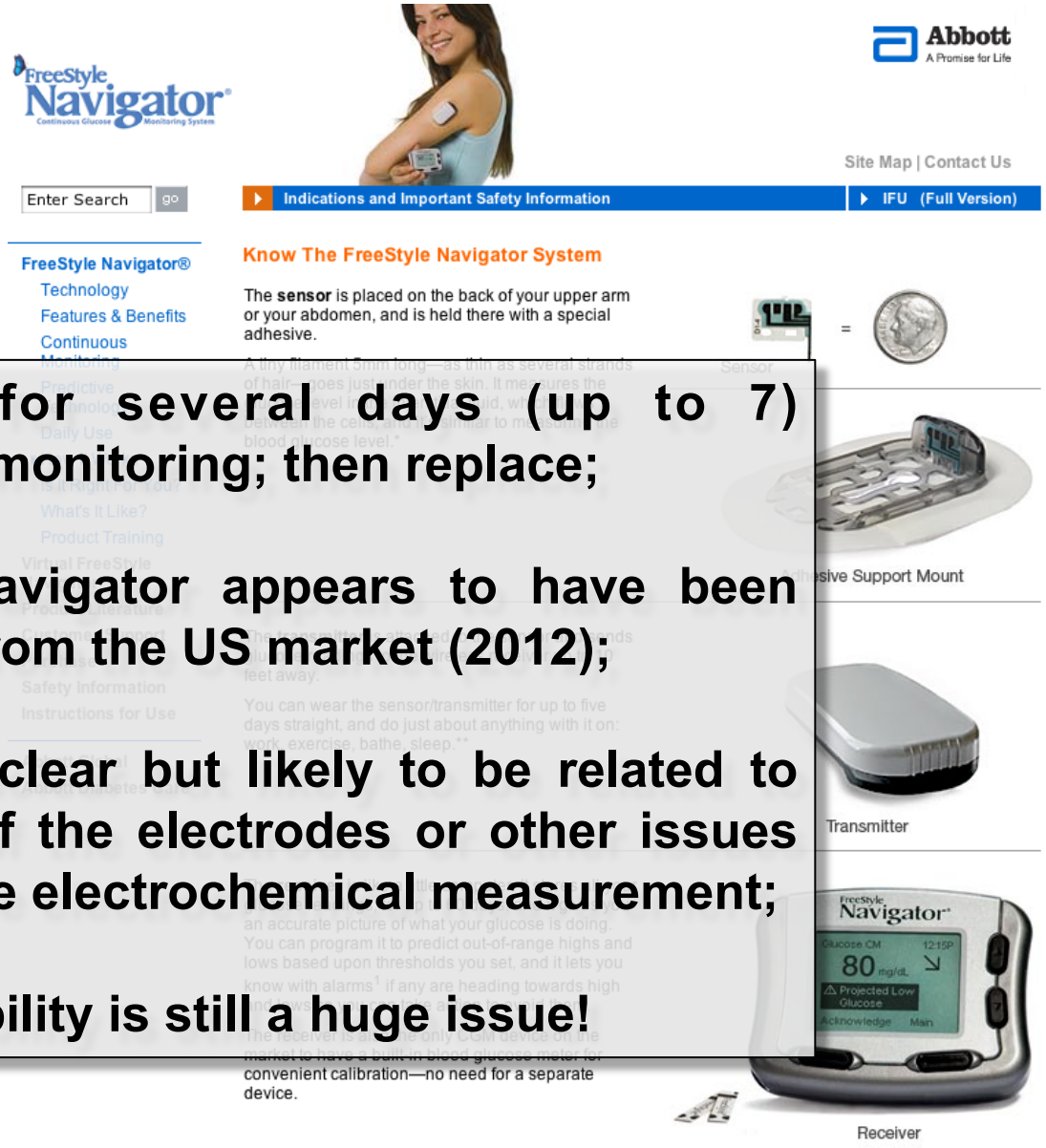
- Combines microfluidics with a micro-dimensioned filament sampling unit which is designed to minimise incidence of infection (therefore can be left in place for 5 days).
- Measures glucose in interstitial fluid (not blood). Diabetics have poor peripheral blood flow so therefore this is easier in advance.
- Wireless communications used to harvest data continuously, and relay to carers and specialists. Enables trending, aggregation, warning….

Target is for several days (up to 7) continuous monitoring; then replace;

Freestyle Navigator appears to have been withdrawn from the US market (2012);

Reasons unclear but likely to be related to biofouling of the electrodes or other issues related to the electrochemical measurement;

Biocompatibility is still a huge issue!



So where are we?

- **The dominant model for success (outside specialised laboratories) in clinical applications for chemical sensors and biosensors is primarily based on 'single shot' or at best short-term use (hours, days), employing disposable devices.**
- **Long-term chemo/bio-sensor implants are still a long way off.**
  - Fundamental breakthroughs are required to make progress
- **In the meantime, on-body sensing (non- or minimally-invasive…..) offer opportunities.**

What sample do we go for?
blood, sweat, tears……..

The technology is happening… Jawbone

UP24™
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Jawbone UP24

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MATERIALS & CARE
Band: hypoallergenic TPU rubber
Cap: TR-90 Nylon, plated in Nickel
Splash-resistant, but do not submerge
Avoid excessive bending

UP BAND DIMENSIONS & WEIGHT
Small
- 52 mm W × 35 mm H (inner)
- 66 mm W × 50 mm H (outer)
- 19 g

Medium
- 63 mm W × 40 mm H (inner)
- 76 mm W × 54 mm H (outer)
- 22 g

Large
- 69 mm W × 43 mm H (inner)
- 81 mm W × 56 mm H (outer)
- 23 g

POWER & BATTERY
Up to 7 days of battery life
32mAh battery Lithium-ion polymer battery
Charge time approximately 80 minutes via USB charging cable

SENSOR & INTERFACE
Bluetooth® 4.0 BLE
Tri-axis accelerometer
Two single color LEDs and vibrating motor indicates power, charge states and current status

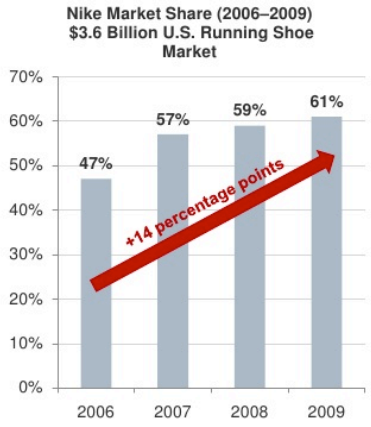
SOFTWARE
Compatible Devices
- iPhone 4s and newer
- iPod Touch 5th Gen and newer
- iPad 3rd Gen and newer
- iPad mini and newer
- Select Android Devices
- Android 4.3 and later
- Bluetooth® Smart Ready

Initially Tied to an iPod, Nike+ Expanded to Other Devices

Nike+ was launched in 2006, and within a year 500,000+ runners from 160+ countries had signed on. Through Aug. 2007, Nike had captured 57% of the $3.6 billion US running shoe market, compared with 47% in 2006.

By Aug. 2009, over 1.3 million runners had uploaded more than 150 million miles on Nike+. Nike's share of the US running show market had increased to 61% – although Nike shoes are not required to use Nike+.

Nike+ Led to Significant Financial Results



$500 Million in Revenue
with $50 Million Less Advertising

Moves & Facebook – Leveraging embedded mobile phone sensors

Moves App to Replace Fitness Wristbands and Gadgets, Following a Recent $1.6m Investment Round

24 January 2013

ProtoGeo Ltd today announces the launch of the Moves app, a new way to track physical activity by simply carrying your smartphone. The company has recently raised $ 1.6 million (≈ € 1.2 million) of seed funding, led by **Lifeline Ventures** and **PROfounders Capital** to make activity tracking easier than ever.

The Moves app tracks users' physical activity by automatically recognizing movement such as walking, cycling, running and transportation. The free iPhone app tells users how much they move, shows routes on a map and provides a simple daily storyline of their life. This information can help people take control of their habits, encouraging small daily changes that can positively impact their overall physical health and well-being.

Moves iPhone app tracks daily physical activity like Fitbit or Nike+ Fuelband but there is no need to charge, carry and buy yet another device. Compared to current fitness wristbands and gadgets, the free Moves app is much more convenient and affordable, by having the functionality within the mobile phone. Unlike traditional sports tracker apps, there is also no need to start and stop the app, which continually works in the background. This makes Moves a more discreet and accessible health tracking option for the everyday casual user.

Moves joins Facebook!

24 April 2014 – Today, we're delighted to announce that Facebook has acquired our company and the Moves app. Since we launched Moves, we've been focused on running a simple and clean activity diary that millions of people have enjoyed using.

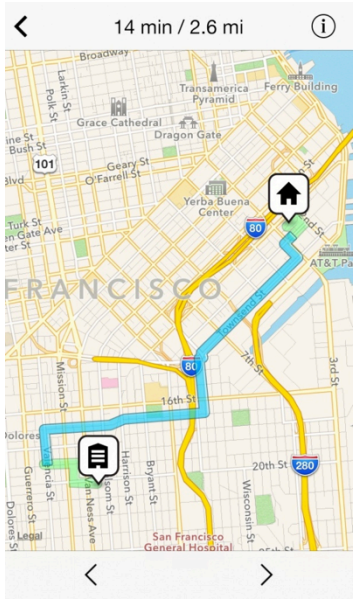
Now, we're joining Facebook's talented team to work on building and improving their products and services with a shared mission of supporting simple, efficient tools for more than a billion people.

For those of you that use the Moves app – the Moves experience will continue to operate as a standalone app, and there are no plans to change that or commingle data with Facebook.

Thank you for supporting us on this journey, and we're looking forward to our future at Facebook!

About Moves

Moves is developed and run by ProtoGeo Oy. The company was founded in Jan 2012 in Helsinki, Finland, to develop a pioneering all-day activity diary for smartphones. Launched in Jan 2013, and called by Apple as 'surprise hit', Moves has been downloaded 4 million times to date for iPhone and Android phones. ProtoGeo raised seed funding from **Lifeline Ventures**, **PROfounders**, **AJP Holding**, Juha Lindfors, **Jyri Engeström** and **Tekes**.



April 2014: INTEL acquires BASIS

Nike & Apple

Nike FuelBand Was the First Fitness Tracker to Fall, But It Won't Be the Last

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WHAT'S THIS?

BY PETE PACHAL

20 HOURS AGO

When Nike laid off big chunks of its FuelBand team on Friday, the future of fitness trackers was suddenly in question. Nike, after all, has one of the most active fitness communities in Nike+, and its FuelBand hardware received generally good reviews. Why run for the exit now?

However, Nike isn't leaving behind wearables *per se*; it's just not going to make any new hardware. The company said it will continue to support existing FuelBands, and its team will work to adapt the software for more platforms. Given Nike's close ties to Apple, this only fuels speculation about an upcoming release of the long-rumored Apple wearable — the iWatch.

Nike Layoffs Add Fuel to Apple iWatch Rumors

ADARIO STRANGE / 3 days ago

Layoffs at Nike's FuelBand unit took many by surprise when the news broke Friday, a move that has further fueled speculation that Apple may be working with the sports-apparel maker to develop an iWatch. A CNET report described the first rumblings of ...

2.7K SHARES

Report: iWatch to Get LG-Made Flexible Display

SAMANTHA MURPHY KELLY / Apr 15, 2014

The much-anticipated Apple iWatch may come with a flexible display manufactured by LG, a new report suggests.

6.7K SHARES

Pebble Sold 400,000 Smartwatches in 2013

APPADVICE / Mar 21, 2014

Pebble is definitely proving the smartwatch market is growing. The company sold 400,000 devices last year, snagging somewhere around $60 million in revenue. And in 2014, the company is well on track to double that revenue number. Talking with Fortune...

4.6K SHARES

Apple's Jony Ive on Design Theft, the Joy of Ignorance and the iWatch

ADARIO STRANGE / Mar 17, 2014

In a rare and wide-ranging interview, Apple's design chief Jony Ive offers a few new insights into one of the most secretive technology companies on the planet -- and explained why he, like his late mentor Steve Jobs, takes it personally when other c...

Intel Buys Wearables Company Basis Science

TODD WASSERMAN / Mar 25, 2014

Intel on Tuesday announced it has purchased Basis Science, the company behind the Basis Band health tracker. Terms of the deal were not disclosed, but TechCrunch reported earlier this month that Intel was paying around $100 million for the company. F...

Apple Prepping Sensors That Predict Heart Attacks, Report Says

ADARIO STRANGE / Feb 16, 2014

We now know that Apple held closed-door talks with Tesla, a meeting of two innovative companies that hints at a number of possibilities. But buried in that same report from the San Francisco Chronicle is the news that Apple may also be preparing to r...

5.6K SHARES

Apple Continues Hiring Spree to Develop iWatch

SAMANTHA MURPHY KELLY / Feb 13, 2014

Apple is still making hires to work on its much-anticipated iWatch.

1.9K SHARES

Apple iWatch

Yes, it looks like the Apple smartwatch will be called the 'iWatch'

WEARABLES

By Chris Smith on Apr 22, 2014 at 7:15 PM
Email @chris_writes

Now that Apple has been seen further extending its company trademark to cover Class 14 devices including watches, a new piece of evidence seems to indicate that there's apparently little doubt as to what Apple's smartwatch will be called. French publication *Consomac* has discovered that Apple has quietly applied for "iWatch" trademarks in many markets around the world, including the U.S., by using a discrete dummy company called Brightflash.

Registered in Delaware, Brightflash USA LLC has filed for iWatch trademark registrations in the U.S., European Union, U.K., China, Australia and many other countries. Apparently Brightflash has the same address Apple is suspected to have used in the past for a similar company to covertly register potential iPad name iSlate. Similarly, a "Carplay Enterprises" company registered at the same address, filed for the CarPlay trademark.

Rumored 'Healthbook' App for iOS 8 Suggests Significant Health Component to iWatch

Friday January 31, 2014 1:52 pm PST by Jordan Golson

Apple is developing a new app expected to be released alongside iOS 8 that collects and organizes information and data points related to the users health, including fitness statistics from the new M7 processor in the iPhone 5s, and possibly other data collected from a new wearable product, reports *9to5Mac*.

The app, reportedly called *Healthbook*, will be a preinstalled app that can track data points including a user's blood pressure, hydration, heart rate and potentially other statistics like glucose levels. It could also remind users to take medications at certain times during the day.

> *The "Healthbook" application is said to take multiple user interface cues from Apple's own Passbook app, which is software for storing loyalty cards, coupons, and other materials normally stored in physical wallets.*
>
> *The new health and fitness application's interface is a stack of cards that can be easily swiped between. Each card represents a different fitness or health data point. The prototype logo for "Healthbook" is similar to Passbook's icon, but it is adorned with graphics representing vital signs.*

9to5Mac also reports that Apple is designing iOS 8 with the iWatch in mind, saying that sources suggest the iWatch and iPhone will be "heavily reliant" on each other for health tracking. The iWatch will also include some mapping abilities as well.

The site suggests that the iWatch will include the ability to measure statistics that the *Healthbook* app can measure -- including glucose levels and heart rate -- though nothing concrete is known. It does say that sources suggest Apple has been able to combine several different health sensors into one chipset in order to make them all smaller.

Apple is also working on significant new features for its *Maps* app, including transit directions, though that feature still has significant amounts of work to be done and is not a "lock" to be included in iOS 8, claims the site.

The New York Times reported earlier today that several Apple executives met with the FDA last month to discuss mobile medical applications. One expert said the meeting could be "to get the lay of the land for regulatory pathways with medical devices and apps" or "that Apple has been trying to push something through the F.D.A. for a while and they've had hangups."

Apple has made a number of health-related hires in the past year, including employees with expertise in health sensors and other mobile health devices.

Apple, iWatch & Health Monitoring

Independent.ie

Wednesday 7 May 2014

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Apple hiring medical device staff, shares break $600 mark

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Apple Inc CEO Tim Cook

UPDATED 06 MAY 2014 10:50 PM

Apple is building a team of senior medical technology executives, raising hackles in the biotechnology community and offering a hint of what the iPhone maker may be planning for its widely expected iWatch and other wearable technology.

May 7th 2014

'**Over the past year, Apple has snapped up at least half a dozen prominent experts in biomedicine**, according to LinkedIn profile changes.

Much of the hiring is in sensor technology, an area Chief Executive Tim Cook singled out last year as primed "to explode."

Industry insiders say the moves telegraph a vision of **monitoring everything from blood-sugar levels to nutrition, beyond the fitness-oriented devices now on the market.'**

"This is a very specific play in the bio-sensing space," said Malay Gandhi, chief strategy officer at Rock Health, a San Francisco venture capital firm that has backed prominent wearable-tech startups, such as Augmedix and Spire.

Google Contact Lens

United States Patent Application ***20140107445***

Kind Code A1 **Liu; Zenghe** **April 17, 2014**

Microelectrodes In An Ophthalmic Electrochemical Sensor

Abstract

An eye-mountable device **includes an electrochemical sensor embedded in a polymeric material** configured for mounting to a surface of an eye. **The electrochemical sensor includes a working electrode, a reference electrode, and a reagent that selectively reacts with an analyte to generate a sensor measurement related to a concentration of the analyte in a fluid to which the eye-mountable device is exposed.** The working electrode can have at least one dimension less than 25 micrometers. The reference electrode can have an area at least five times greater than an area of the working electrode. A portion of the polymeric material can surround the working electrode and the reference electrode such that an electrical current conveyed between the working electrode and the reference electrode is passed through the at least partially surrounding portion of the transparent polymeric material.

Google Smart Contact Lenses Move Closer to Reality

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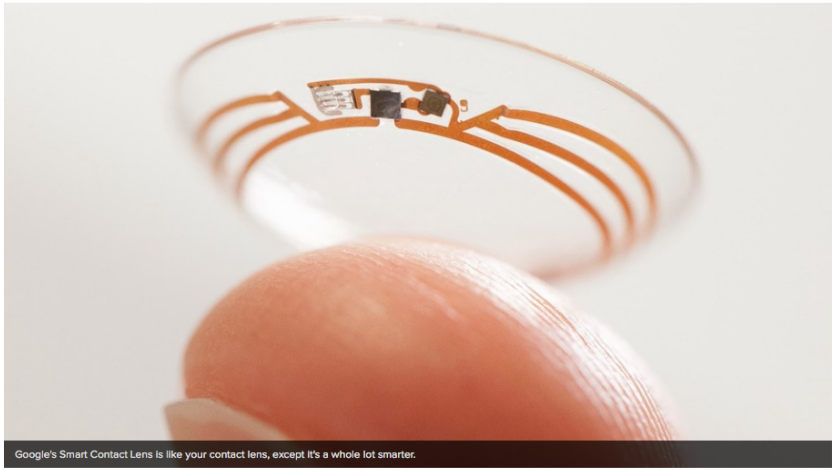


IMAGE: GOOGLE

BY LANCE ULANOFF

1 DAY AGO

Google's plan to bring smart contact lenses to diabetes sufferers inched closer to reality as the company secured two patents last week for the cutting edge, biometric sensor technology.

Known among scientists as "Ophthalmic Electrochemical Sensors," these contact lenses will feature flexible electronics that include sensors and an antenna. The sensors are designed to read chemicals in the tear fluid of the wearer's eye and alert her, possibly through a little embedded LED light, when her blood sugar falls to dangerous levels.

SEE ALSO: 7 Incognito Wearables You'd Never Guess Were Gadgets

According to the patent:

> "Human tear fluid contains a variety of inorganic electrolytes (e.g., Ca.sup.2+, Mg.sup.2+, Cl.sup.-), organic solutes (e.g., glucose, lactate, etc.), proteins, and lipids. A contact lens with one or more sensors that can measure one or more of these components provides a convenient, non-invasive platform to diagnose or monitor health related problems. An example is a glucose sensing contact lens that can potentially be used for diabetic patients to monitor and control their blood glucose level.

Google's project is one of a number of in-eye wearable sensor technologies currently under

http://www.gmanetwork.com/news/story/360331/scitech/technology/google-s-smart-contact-lenses-may-arrive-sooner-than-you-think

Glucose Sensor in a contact lens

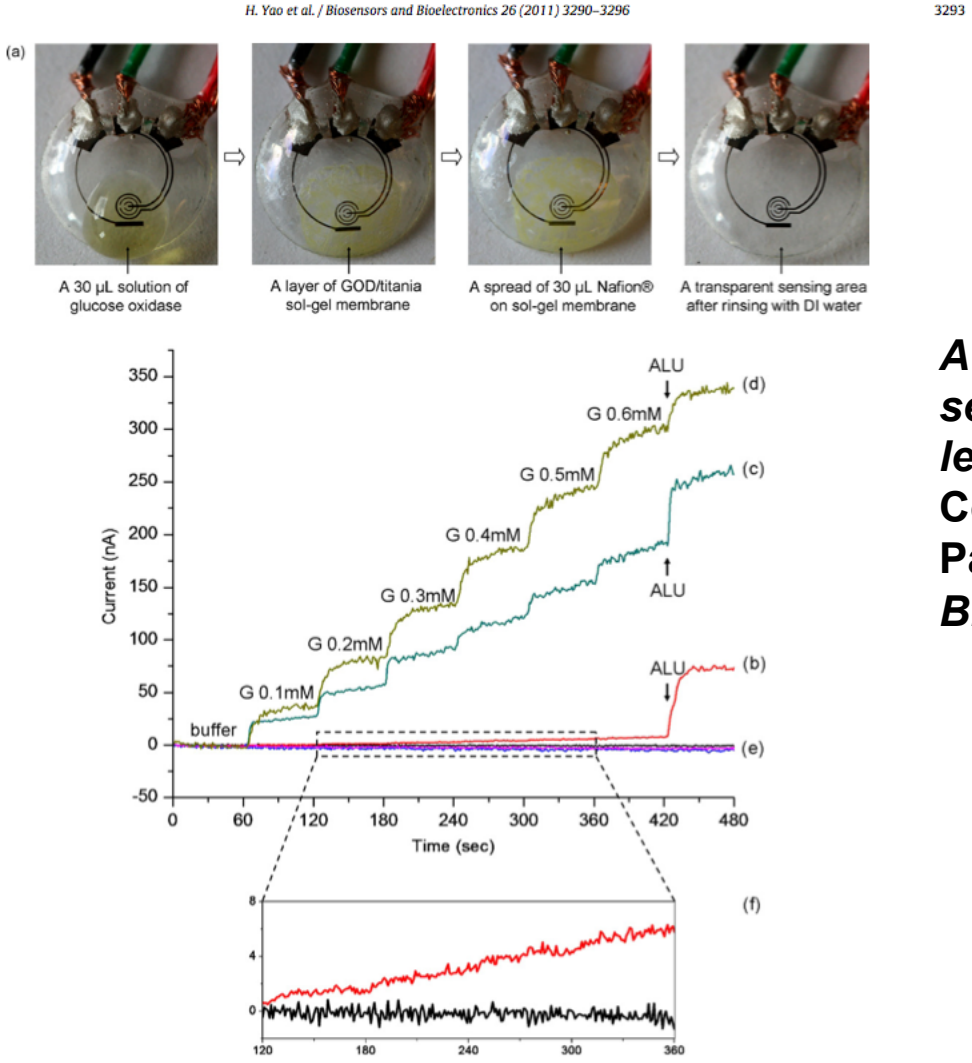
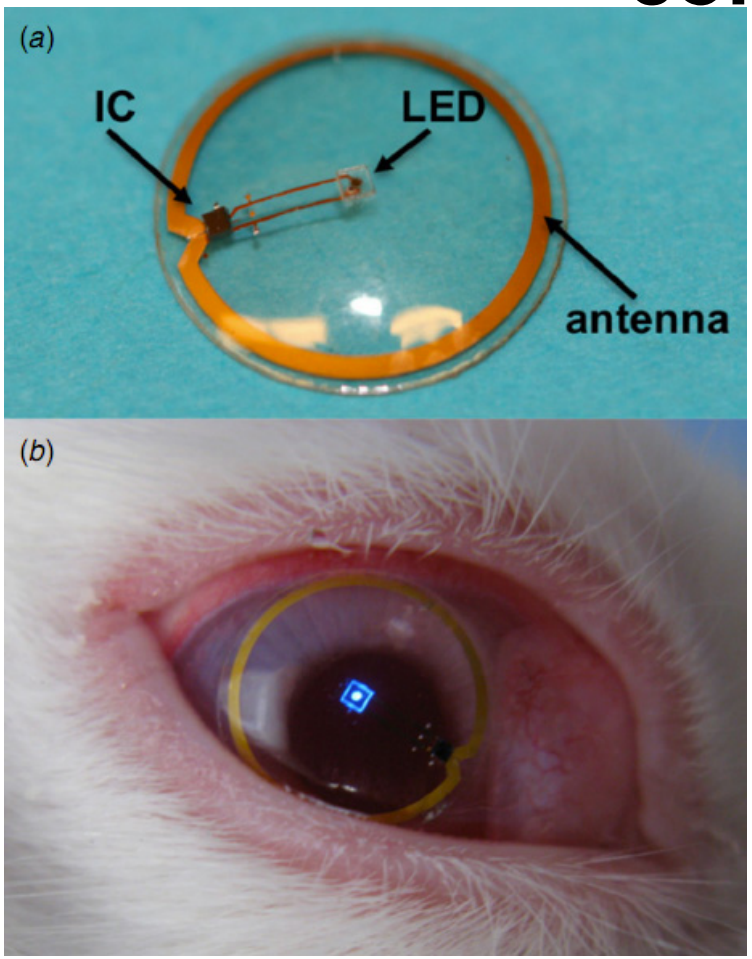


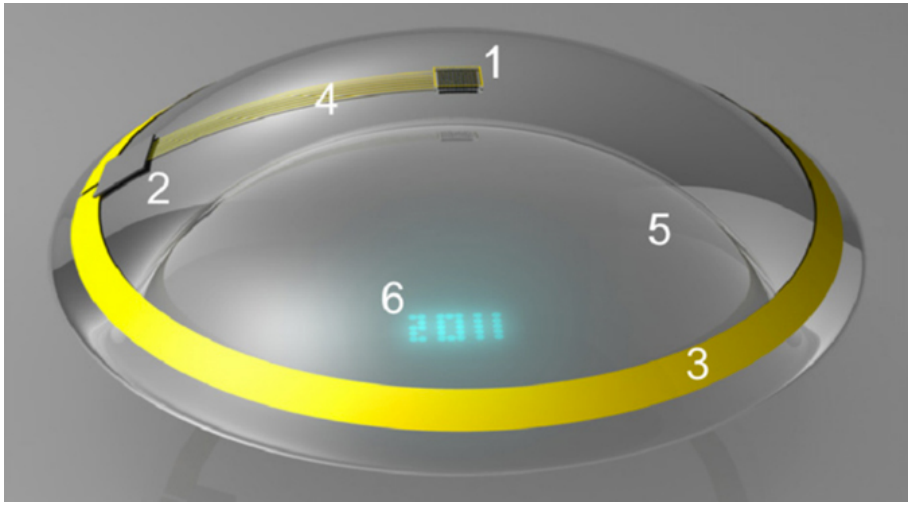
Fig. 2. Images of the sensor as it goes through surface functionalization and the related measured responses: (a) sequential images of sensor pre-treatment with GOD/titania/Nafion®; (b) measured amperometric response for the sensor just incubated with GOD; (c) measured amperometric response for the sensor prepared with GOD/titania sol–gel film; (d) measured amperometric response for the sensor prepared with GOD/titania/Nafion®; (e) three controls (signals for buffer) for the same pre-treatment of (b), (c), and (d); (f) the enlarged view of curve (b) and control of (b) for 120–360 s.

Babak Parviz et al.

A contact lens with embedded sensor for monitoring tear glucose level, **H. F. Yao, A. J. Shum, M. Cowan, I. Lahdesmaki and B. A. Parviz, *Biosensors & Bioelectronics*, 2011, 26**, 3290-3296.

Babak Parviz: LED implanted on a contact lens



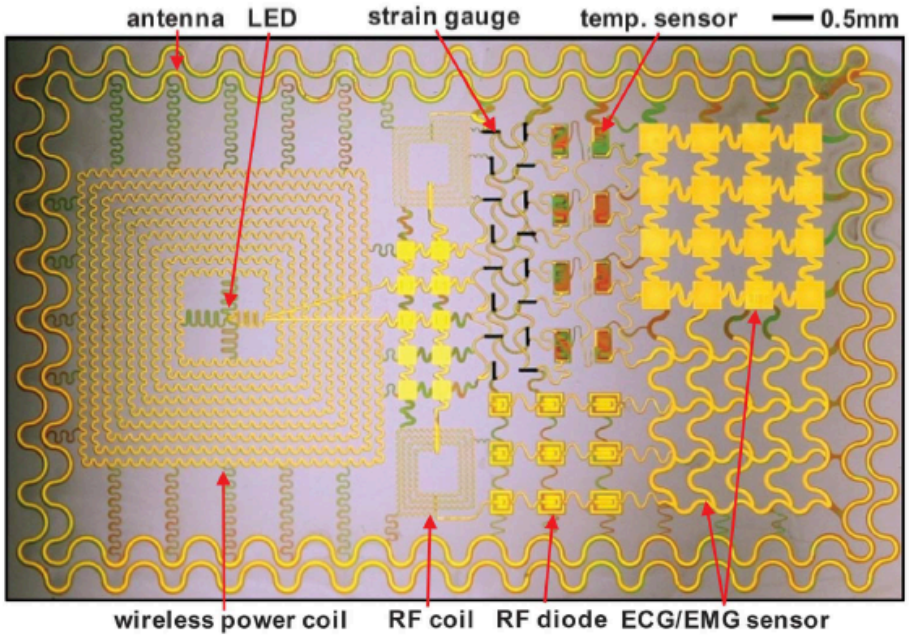


"There's basically just two components, sandwiched between two layers of contact lens material: An antenna and rectifier, and a small glucose sensor. The problem with smart contact lenses, though, is the power source."
"The team, led by Babak Parviz, (University of Washington -> Google) has successfully displayed a single, remotely-controlled pixel onto a contact lens worn by a rabbit. Power from an external battery is transmitted via RF to an antenna that runs around the edge of the contact lens (the gold ring that you see in the image below), so that the wearer's vision isn't obstructed."

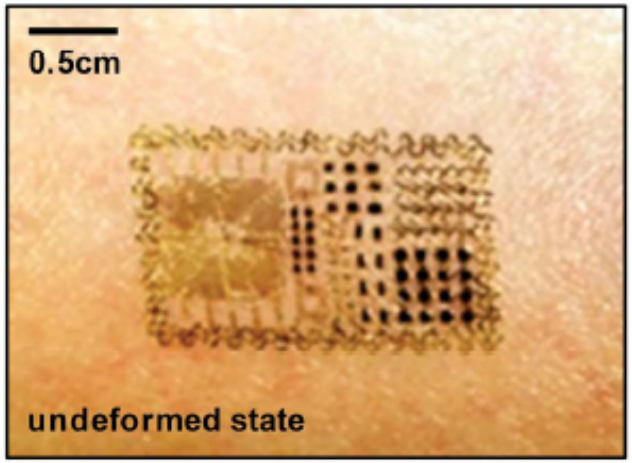
http://www.extremetech.com/extreme/174979-the-next-step-in-googles-cyborg-plans-smart-contact-lenses-for-those-with-diabetes

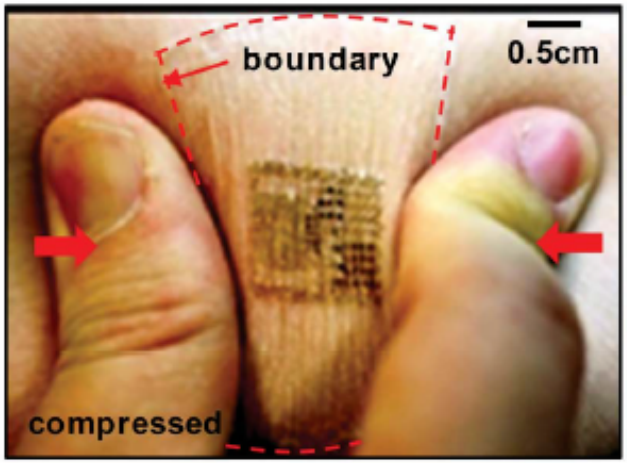
These comments don't mention the issues associated with in-situ biosensing; the real problem will lie in the reliability of the biosensor over the period of typical use.
Perhaps there's a chance, as contact lenses are typically replaced on a daily basis.

Latest Trends – Tattoo format sensors

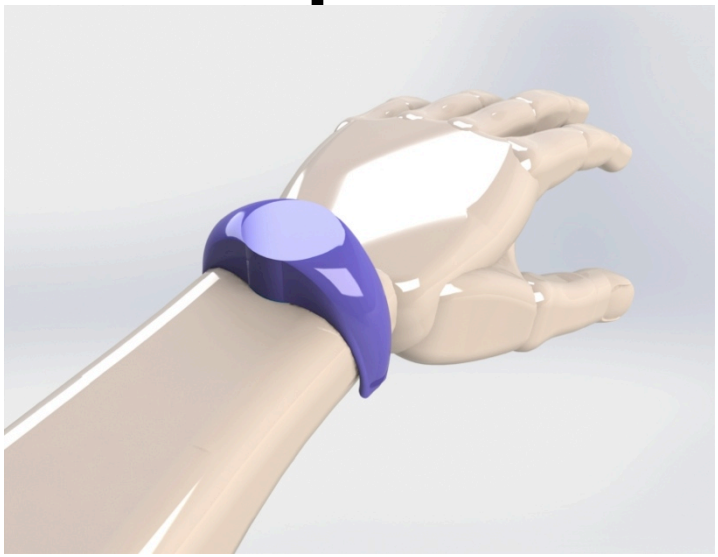


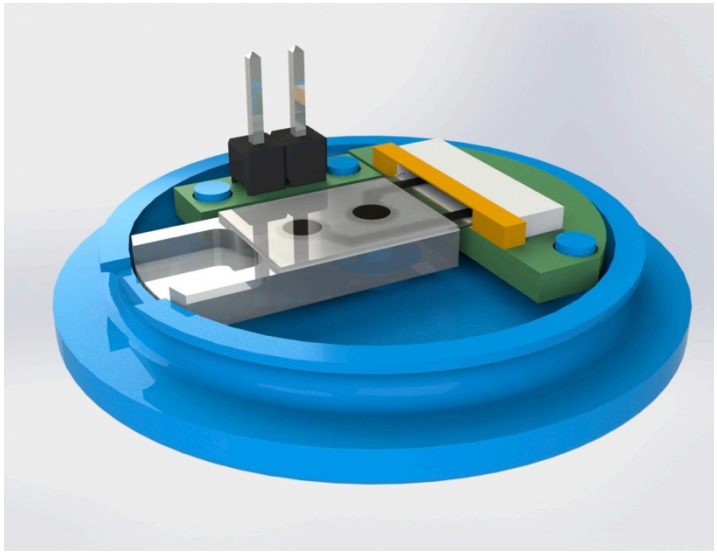
Prof. John Rogers @
University of Illinois

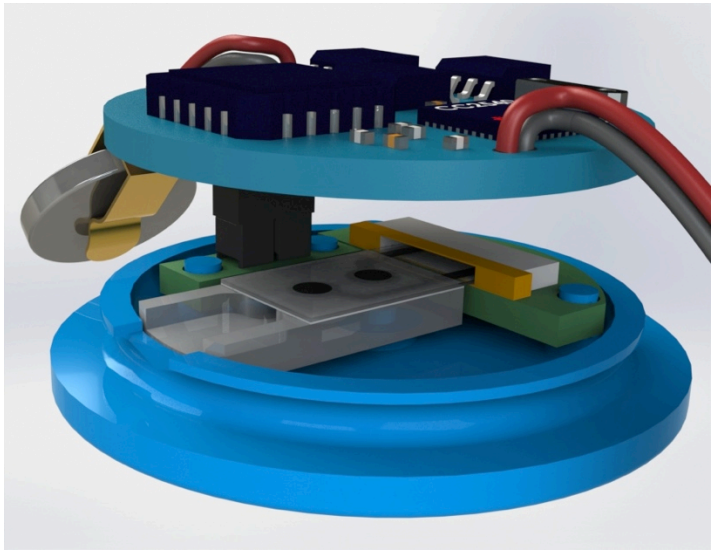




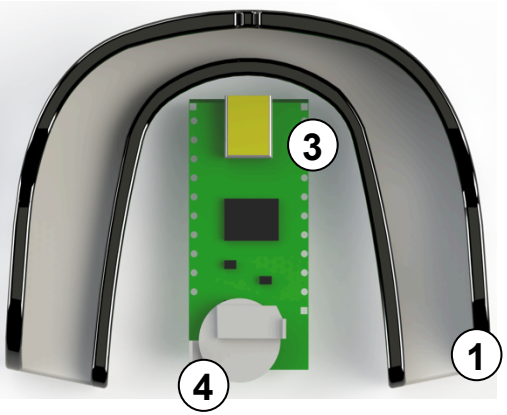
Next Generation: Watch Fluidic Sensor Concept



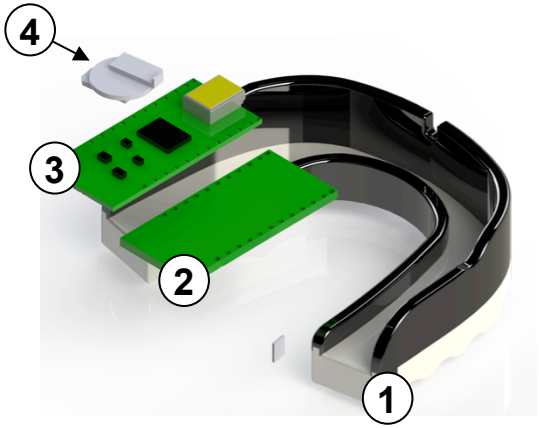




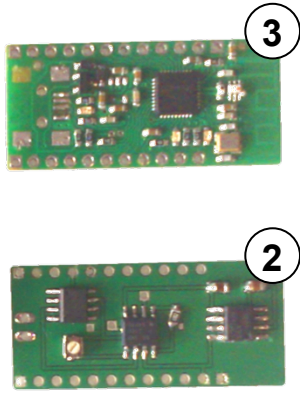
Smart Gumshield

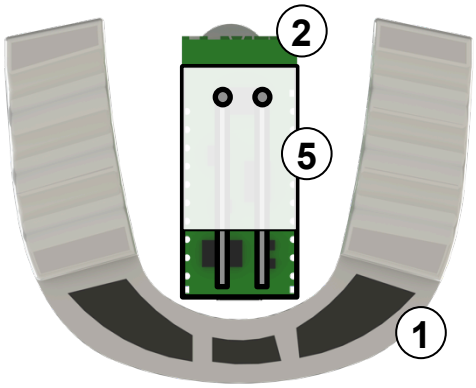


(a) Top View

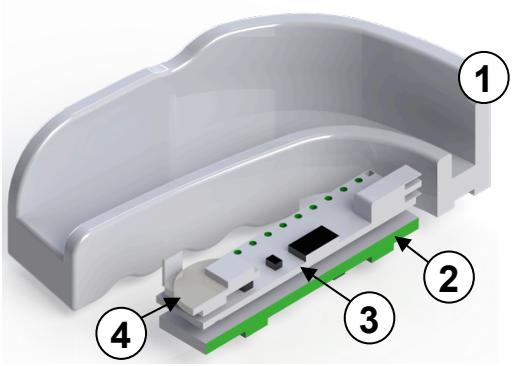


(b) Exploded View

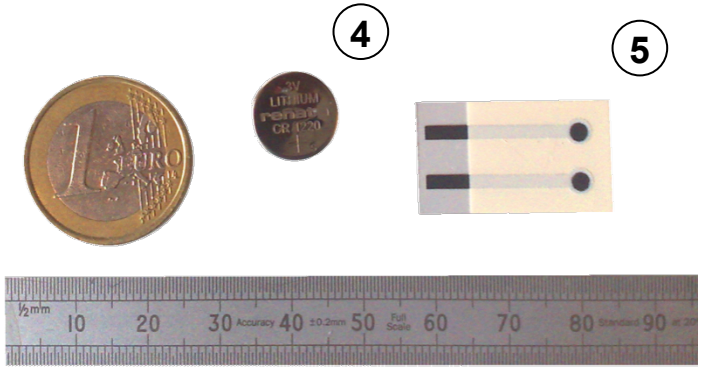




(c) Bottom View



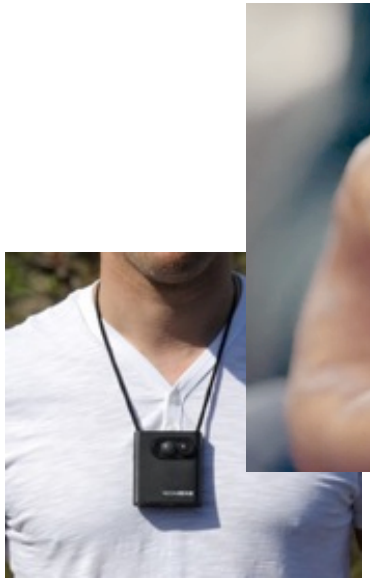
(d) Assembled Sectional View



(e) Photo of components laid out

Wearable Cameras

- **Large marketspace potential**
  - The market for Google Glass hardware alone is estimated to be worth $11B by 2018
  - Global market for wearables in health and fitness could reach 170 million devices by 2017, an annual growth of 41% (AIB research)



ACS Breakthrough Science Videos

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DOI: 10.1021/nn500614k

Using Google Glass for Diagnostics

ARTICLE

Immunochromatographic Diagnostic Test Analysis Using Google Glass

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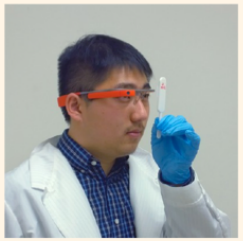
[†]Electrical Engineering Department, [‡]Bioengineering Department, [§]California NanoSystems Institute, and [⊥]Department of Surgery, David Geffen School of Medicine, University of California, Los Angeles, California 90095, United States

ABSTRACT We demonstrate a Google Glass-based rapid diagnostic test (RDT) reader platform capable of qualitative and quantitative measurements of various lateral flow immunochromatographic assays and similar biomedical diagnostics tests. Using a custom-written Glass application and without any external hardware attachments, one or more RDTs labeled with Quick Response (QR) code identifiers are simultaneously imaged using the built-in camera of the Google Glass that is based on a hands-free and voice-controlled interface and digitally transmitted to a server for digital processing. The acquired JPEG images are automatically processed to locate all the RDTs and, for each RDT, to produce a quantitative diagnostic result, which is returned to the Google Glass (*i.e.*, the user) and also stored on a central server along with the RDT image, QR code, and other related information (*e.g.*, demographic data). The same server also provides a dynamic spatiotemporal map and real-time statistics for uploaded RDT results accessible through Internet browsers. We tested this Google Glass-based diagnostic platform using qualitative (*i.e.*, yes/no) human immunodeficiency virus (HIV) and quantitative prostate-specific antigen (PSA) tests. For the quantitative RDTs, we measured activated tests at various concentrations ranging from 0 to 200 ng/mL for free and total PSA. This wearable RDT reader platform running on Google Glass combines a hands-free sensing and image capture interface with powerful servers running our custom image processing codes, and it can be quite useful for real-time spatiotemporal tracking of various diseases and personal medical conditions, providing a valuable tool for epidemiology and mobile health.



KEYWORDS: Google Glass · rapid diagnostic test reader · colorimetric sensor · lateral flow immunochromatographic assays · HIV testing · prostate-specific antigen (PSA) test · mobile health

ACS Nano 8 (3) 3069-3079, 2014

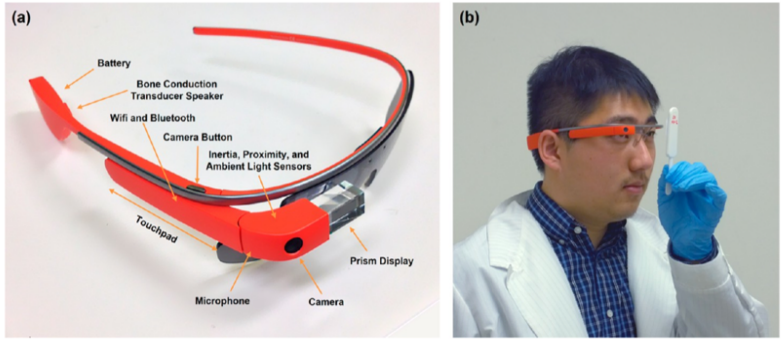


Figure 1. Labeled Google Glass and demonstration of imaging a rapid diagnostic test (RDT). (a) Front-profile view of the Google Glass with various hardware components[36] labeled. (b) Example of using the Glass for taking an image of an RDT as part of our RDT reader application.

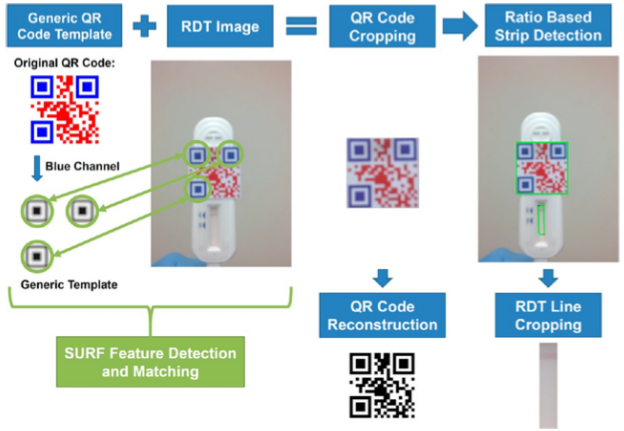


Figure 7. Methodology for finding QR code in a Glass image scene and segmenting the test strip region. Using a generic QR code template, we match location modules across the image using SURF.[67] Detected QR codes are then reconstructed and processed, and the location is used for ratio-based segmentation of the rapid diagnostic test strip region.

Conclusions

- Invasive/implantable chem/bio-sensors that function for 5 or more years (target for pancreas) are still well beyond the state-of-the-art
- Real-time in-situ Chem/Bio monitoring for days is possible
- Use model that involves regular changing of the sensor is the key to success with current technologies
- Breakthroughs will emerge from multi-partner collaborations across industry and academia
- Arrays of short-term use sensors are possible, provided low cost liquid handling approaches can be realised

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Thanks for the invitation