Biosensori e riparazione tessutale cutanea

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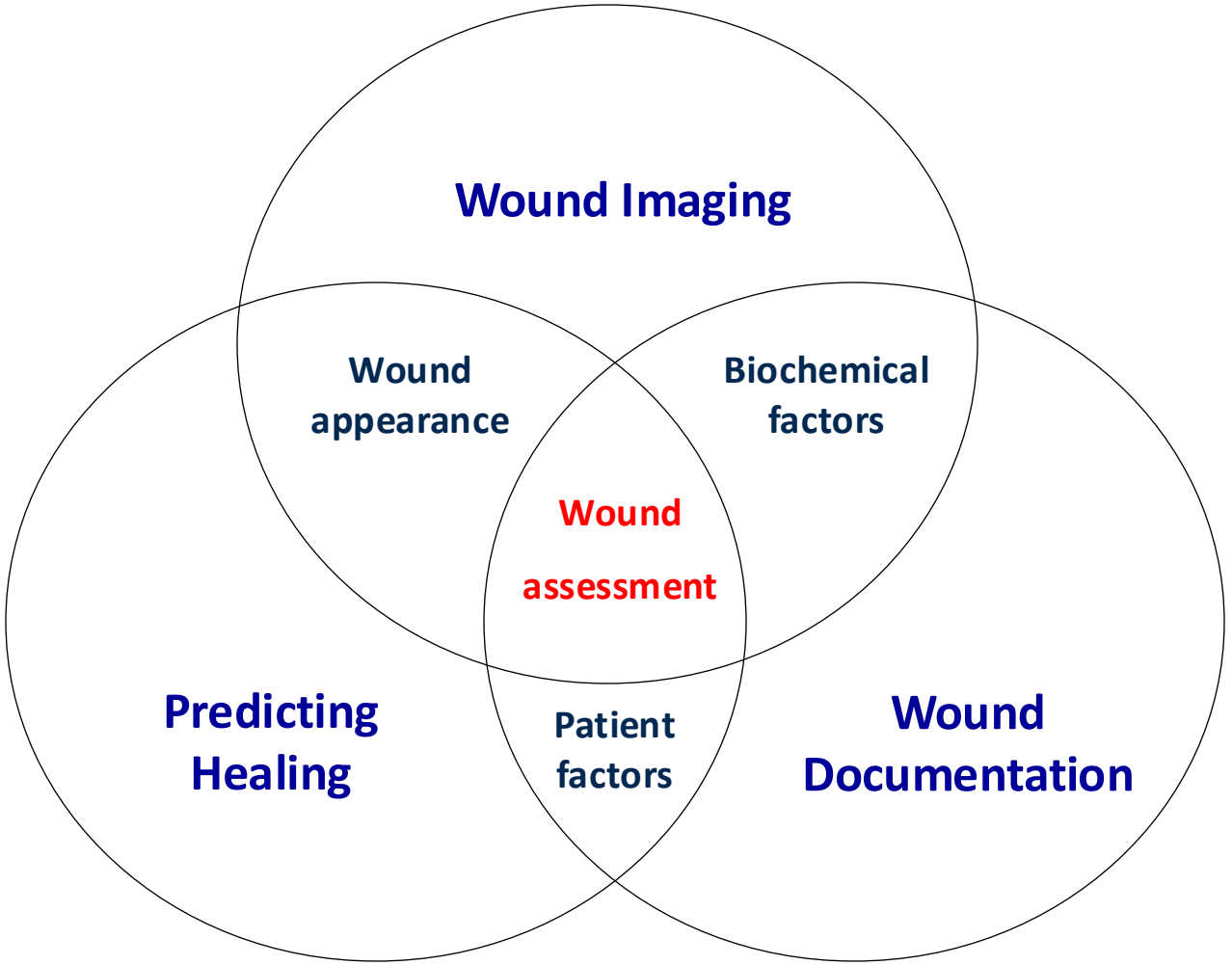
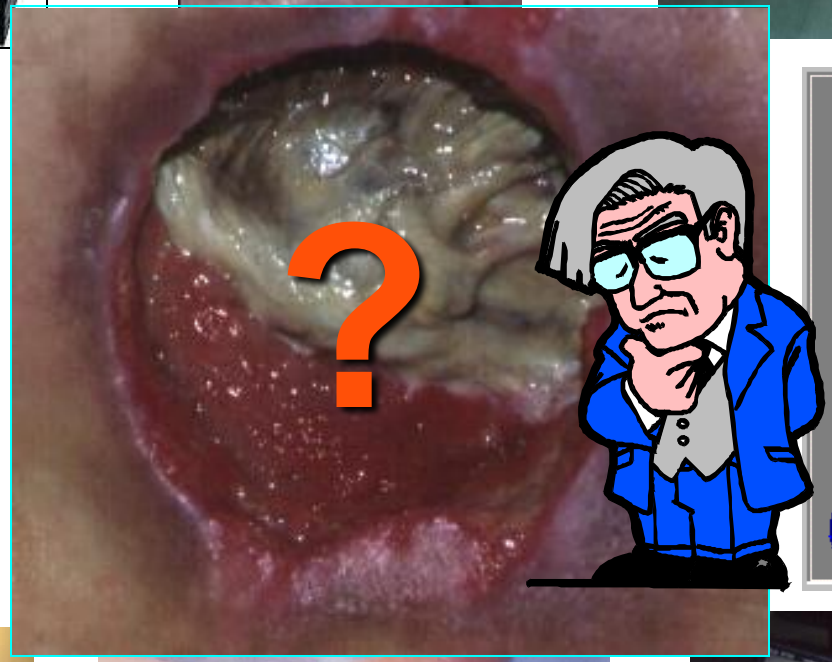
Disclosures

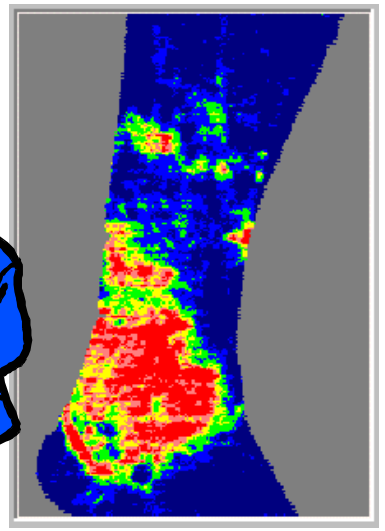
- Abbvie
- ConvaTec
- Lilly
- Medskin
- Novartis
- Urgo
- Sanofi

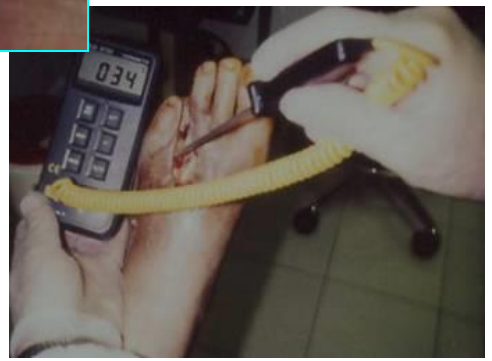
Assessing Wound Healing



SWAN iCare

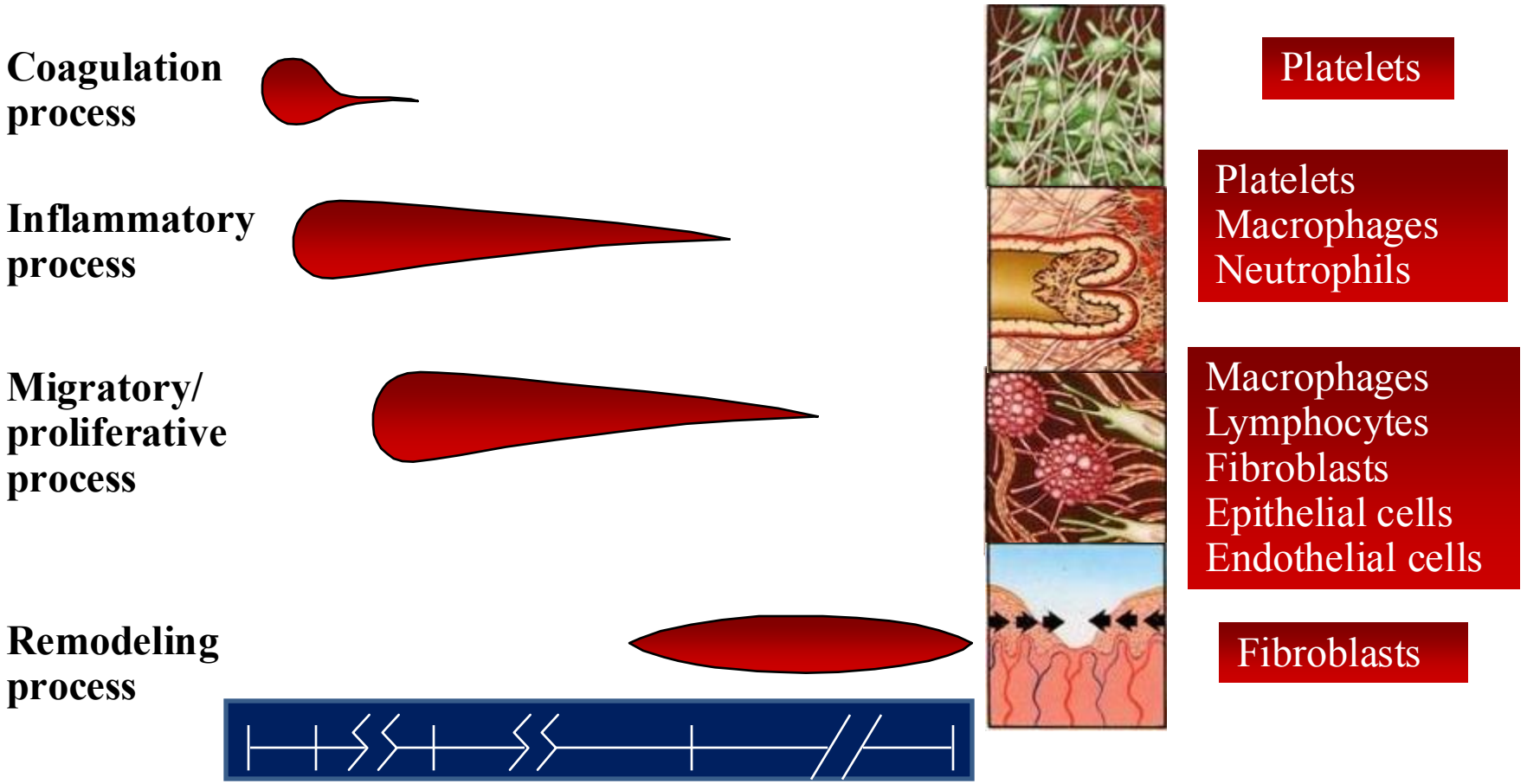






SWAN iCare

Wound Healing



Kane DP, Krasner D. In: Chronic Wound Care. 2nd ed. Health Management Publications Inc; 1997:1-4

Purpose of Wound Assessment

Better understanding of the processes which impair healing

- Diagnosis
- Clinical decision support

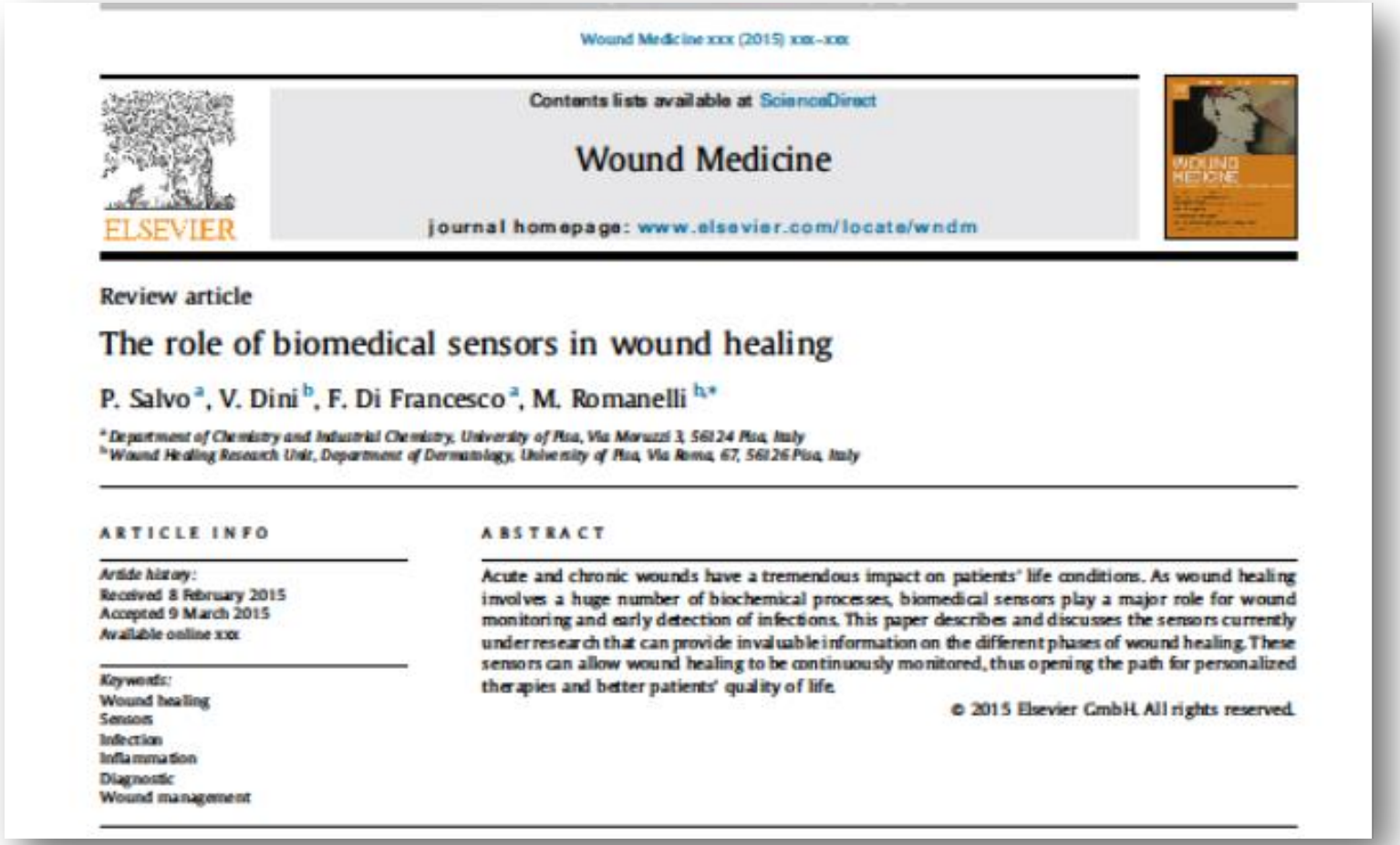
Outcomes

- Monitoring the effectiveness of treatment
- Prediction of outcome

Prevention wound complications

- Amputation (DFU)
- Infection

The Role of Biomedical Sensors in Wound Healing



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Review article

The role of biomedical sensors in wound healing

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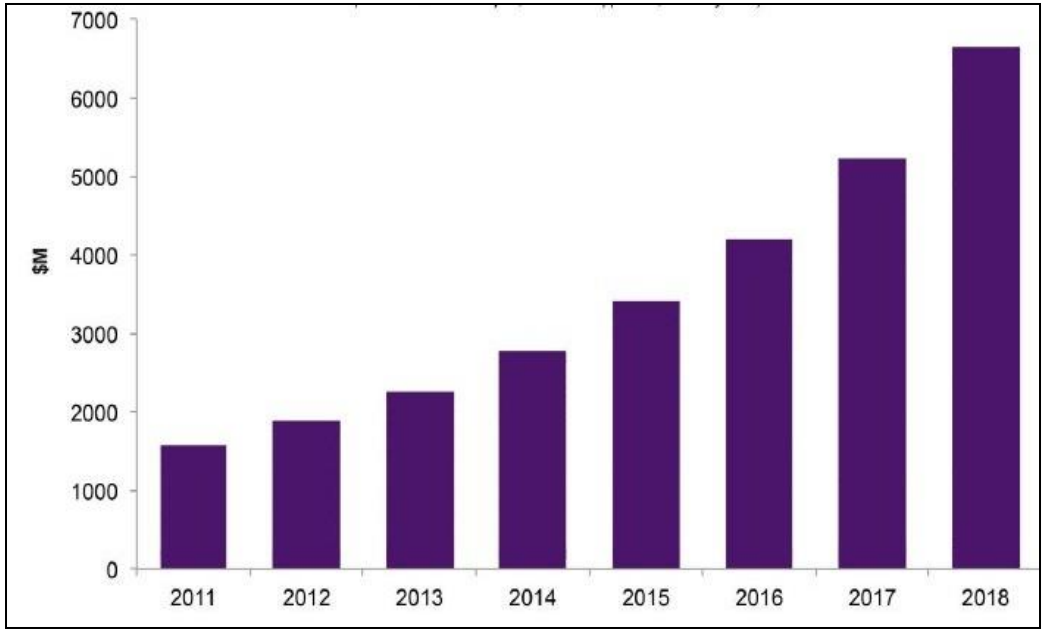
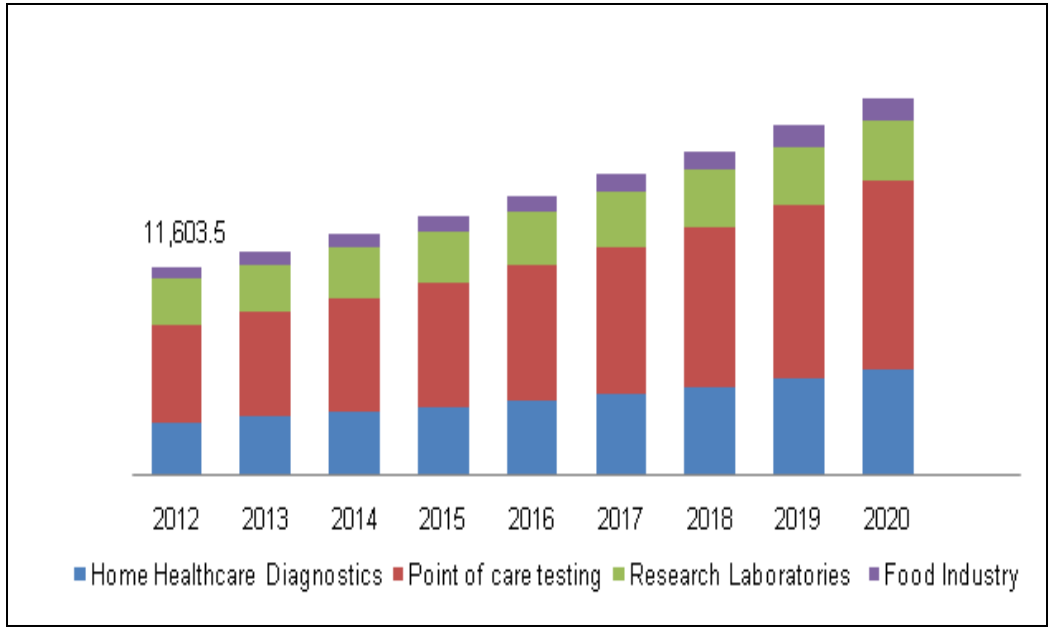
ABSTRACT

Acute and chronic wounds have a tremendous impact on patients' life conditions. As wound healing involves a huge number of biochemical processes, biomedical sensors play a major role for wound monitoring and early detection of infections. This paper describes and discusses the sensors currently under research that can provide invaluable information on the different phases of wound healing. These sensors can allow wound healing to be continuously monitored, thus opening the path for personalized therapies and better patients' quality of life.

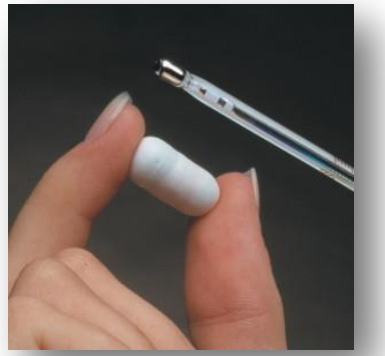
Sensors in the science market





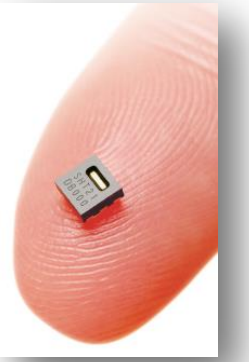
Sensors

A small device that detects and responds to some type of input from the physical environment and sends the information to other electronics.



Biosensors

Sensors which detect analytes thanks to a biological component (cells, protein, nucleic acid or biometric polymers).



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Sensors must be :

- Thin and flexible
- Low cost, disposable
- Suitable for integration in wound dressing
- Biocompatible
- Able to resist in a chemically aggressive environment
- Able to monitor large areas

Flexible sensor chip

Wound Assessment Parameters

Temperature

pH

TEWL

International Journal of Nanomedicine

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ORIGINAL RESEARCH

Temperature- and pH-sensitive wearable materials for monitoring foot ulcers

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Nicola Calisi[1]
Bernardo Melai[1]
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Abstract: Foot ulcers account for 15% of comorbidities associated with diabetes. Presently, no device allows the status of foot ulcers to be continuously monitored when patients are not hospitalized. In this study, we describe a temperature and a pH sensor capable of monitoring diabetic foot and venous leg ulcers developed in the frame of the seventh framework program European Union project SWAN-iCare (smart wearable and autonomous negative pressure device for wound monitoring and therapy). Temperature is measured by exploiting the variations in the electrical resistance of a nanocomposite consisting of multiwalled carbon nanotubes and poly(styrene-b-(ethylene-*co*-butylene)-b-styrene). The pH sensor used a graphene oxide (GO) layer that changes its electrical potential when pH changes. The temperature sensor has a sensitivity of ~85 Ω/°C in the range 25°C–50°C and a high repeatability (maximum standard deviation of 0.1% over seven repeated measurements). For a GO concentration of 4 mg/mL,

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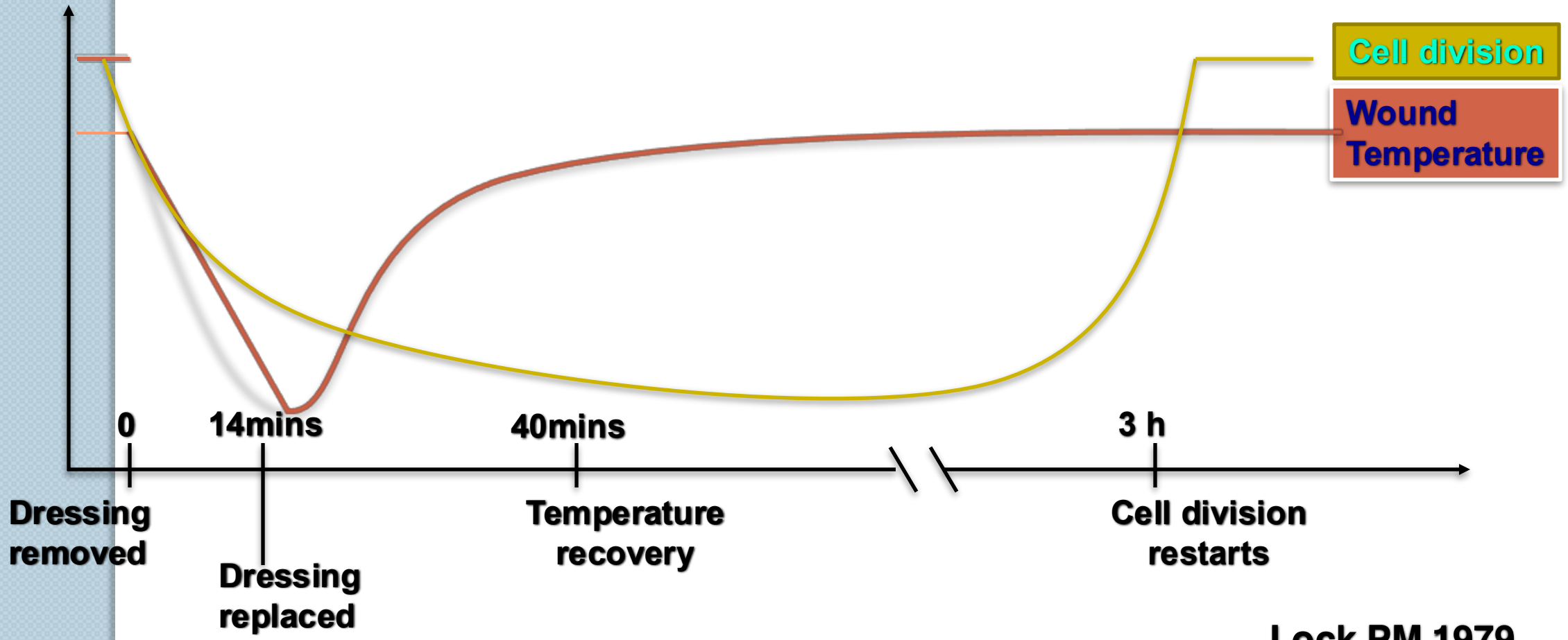
The Role of Temperature in Chronic Wounds

Effect of Cooling on Wounds



Lock PM 1979

The Role of Temperature in Chronic Wounds

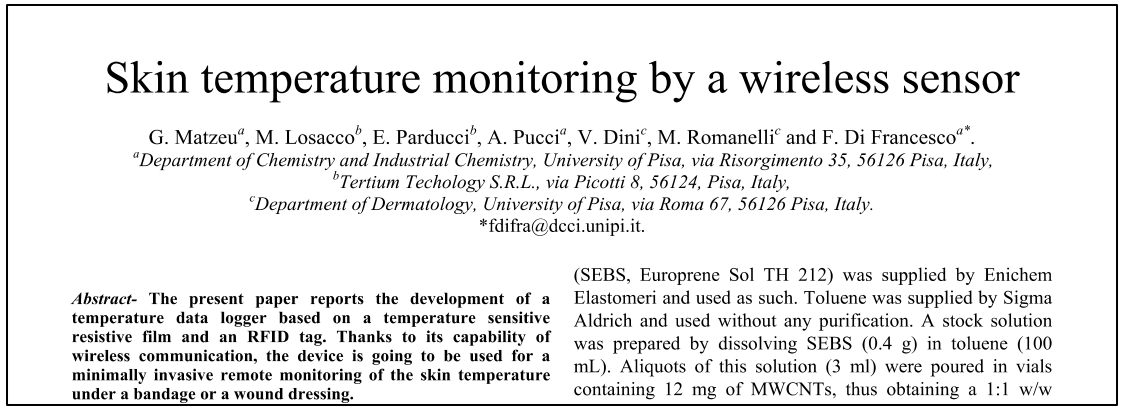
- Increase in temperature is an established marker of infection
- Differences of >4°F were used as the trigger point of ulceration

Amstrong et al. 2007

Temperature sensors

- ✓Resistance temperature detectors
- ✓Thermocouples
- ✓Thermistors
- ✓Infra-red sensors
- ✓Silicone-based sensors

Temperature Sensor



Skin temperature monitoring by a wireless sensor

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***Abstract*- The present paper reports the development of a temperature data logger based on a temperature sensitive resistive film and an RFID tag. Thanks to its capability of wireless communication, the device is going to be used for a minimally invasive remote monitoring of the skin temperature under a bandage or a wound dressing.**

(SEBS, Europrene Sol TH 212) was supplied by Enichem Elastomeri and used as such. Toluene was supplied by Sigma Aldrich and used without any purification. A stock solution was prepared by dissolving SEBS (0.4 g) in toluene (100 mL). Aliquots of this solution (3 ml) were poured in vials containing 12 mg of MWCNTs, thus obtaining a 1:1 w/w

- Wireless
- A mixture of multi-walled carbon nanotubes and poly SEBS (styrene-b-ethylene-co-butylene-b-styrene) that coat a Kapton® substrate.
- The signal can be remotely transmitted by radio frequency identification transceiver.

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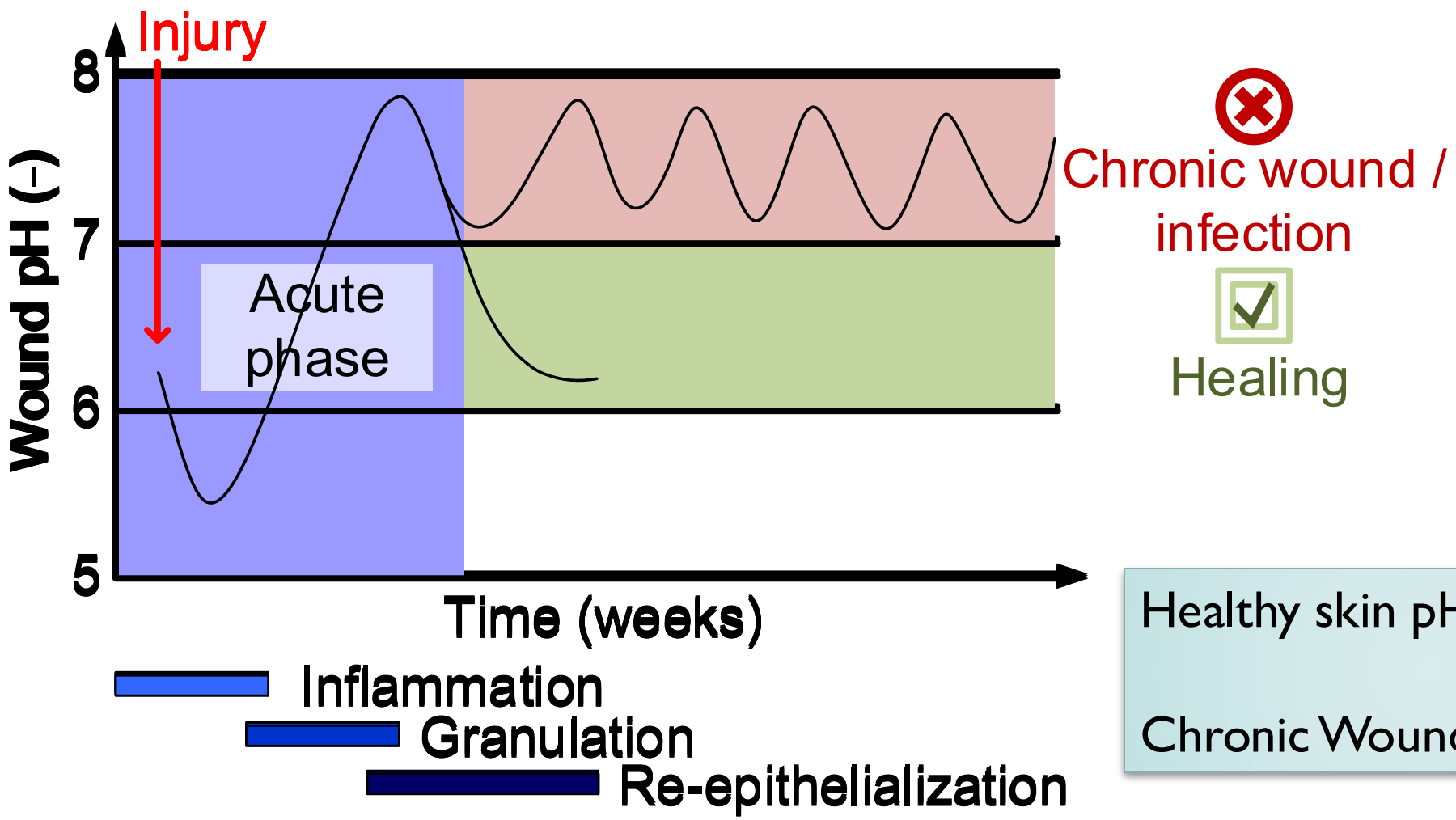
Matzeu. G, Losacco M, Parducci E, Pucci A, Dini V, Romanelli M. et al.
Skin temperature monitoring by a wireless sensor. In: 37° annual conference of the IEEE Industrial Electronics Society, 2011

The Role of pH in chronic wounds



Healthy skin pH : 4.0 to 7.0

Chronic Wounds: 7.0 to 8.0

The Role of pH in chronic wounds

1. pH changes is related to wound healing process

Stage I
5.7 ± 0.5

Stage II
6.9 ± 1.0

Stage III
7.6 ± 0.2

pH value by stanging

Tsukada et al. WOUNDS 1992

2. In Chronic wound an increase in pH is a sign of infection if compared with the normal surrounding skin

Glibbery AB, Mani R. pH in leg ulcers. Int J Microcirc Clin Exp 1992

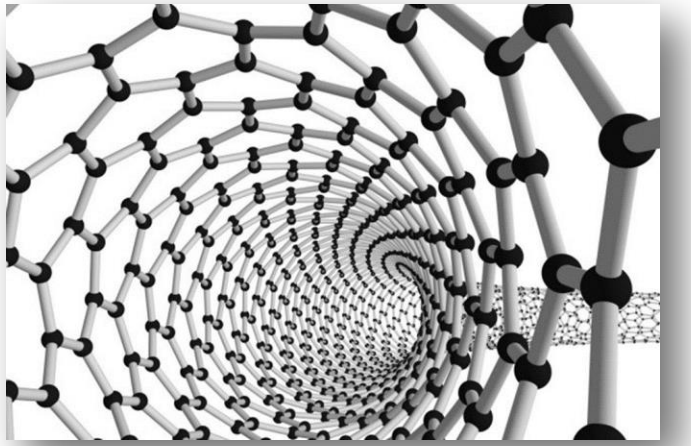
pH measurement

A flat glass electrode in contact with the skin and connected to a potentiometer

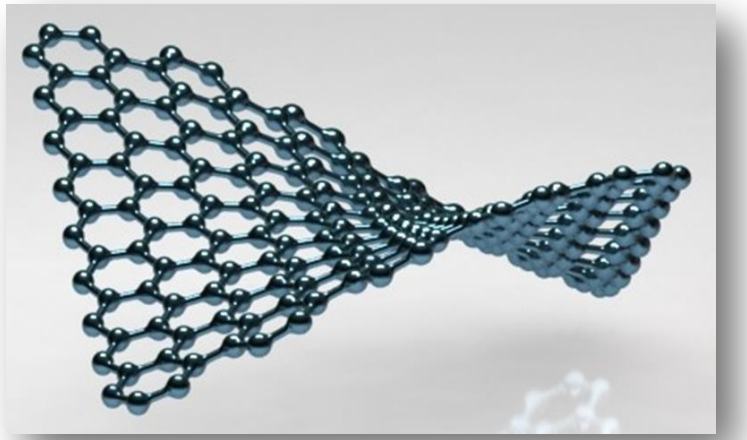
Disadvantage

Impractical for implementation in wound dressing for continuous monitoring

Innovative Sensitive Materials



Carbon nanotube



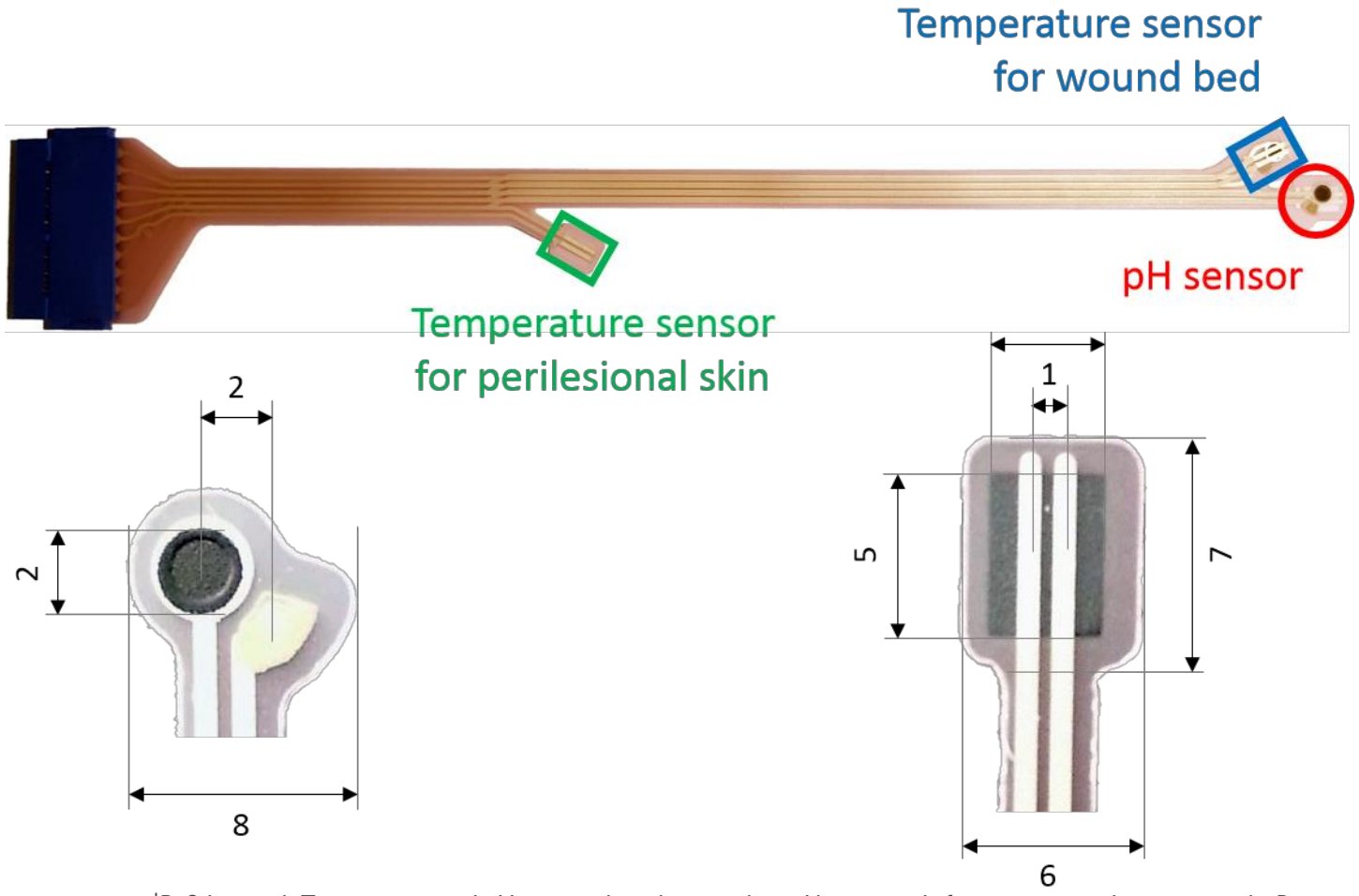
Graphene

Photo: U. Montan
Andre Geim

Photo: U. Montan
Konstantin Novoselov

Sensors fabrication

Graphene Oxide films were deposited by drop casting; for temperature sensing, GO films were reduced by a water solution of ascorbic acid (25 mg/L, 20 minutes at 80 °C)[1].

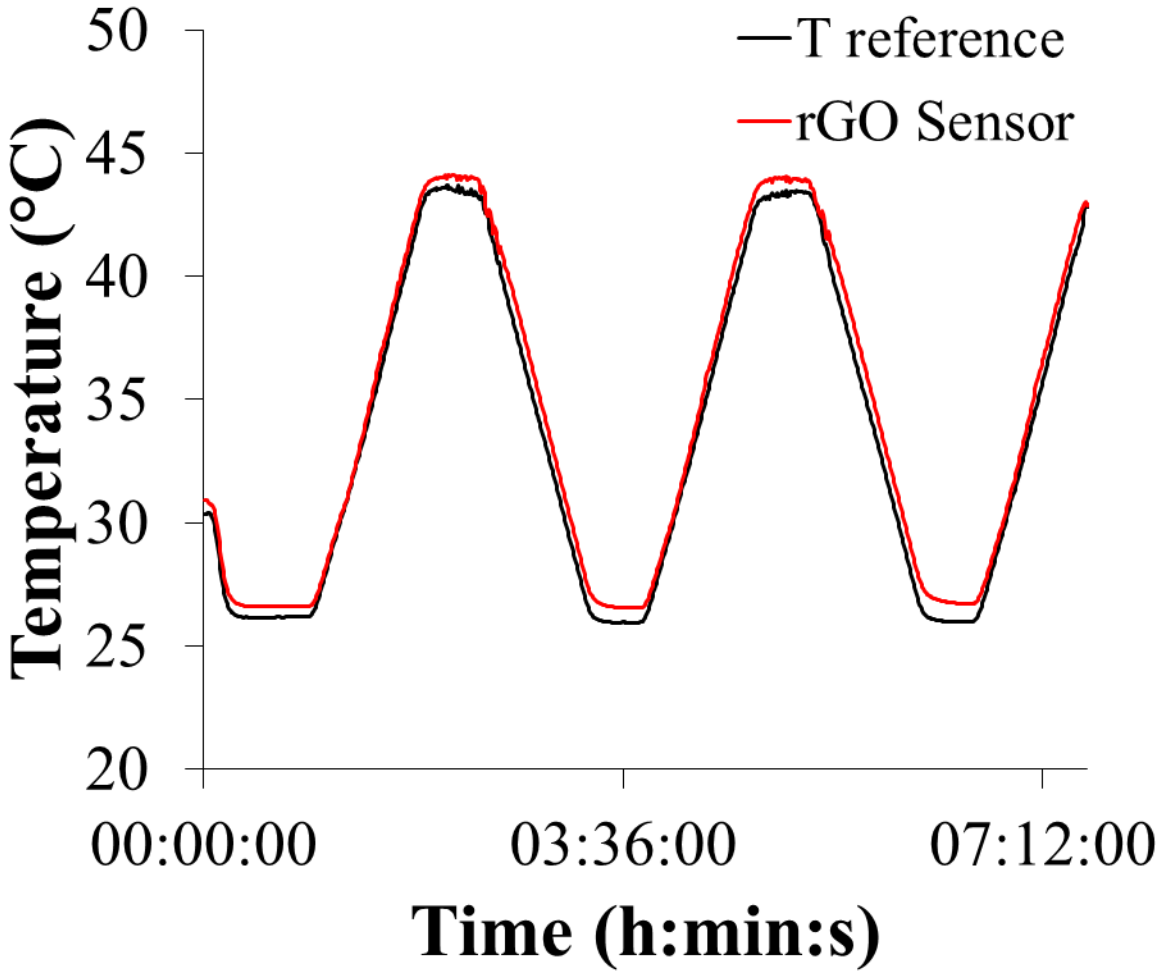


Reduced graphene oxide shows an almost linear dependence of electrical resistivity from temperature

Graphene oxide dispersions in water can be used to prepare pH sensitive films and disposable pH sensors

[1]P. Salvo et al. Temperature and pH sensors based on graphene-like materials for monitoring chronic wounds, Biosensors & Bioelectronics

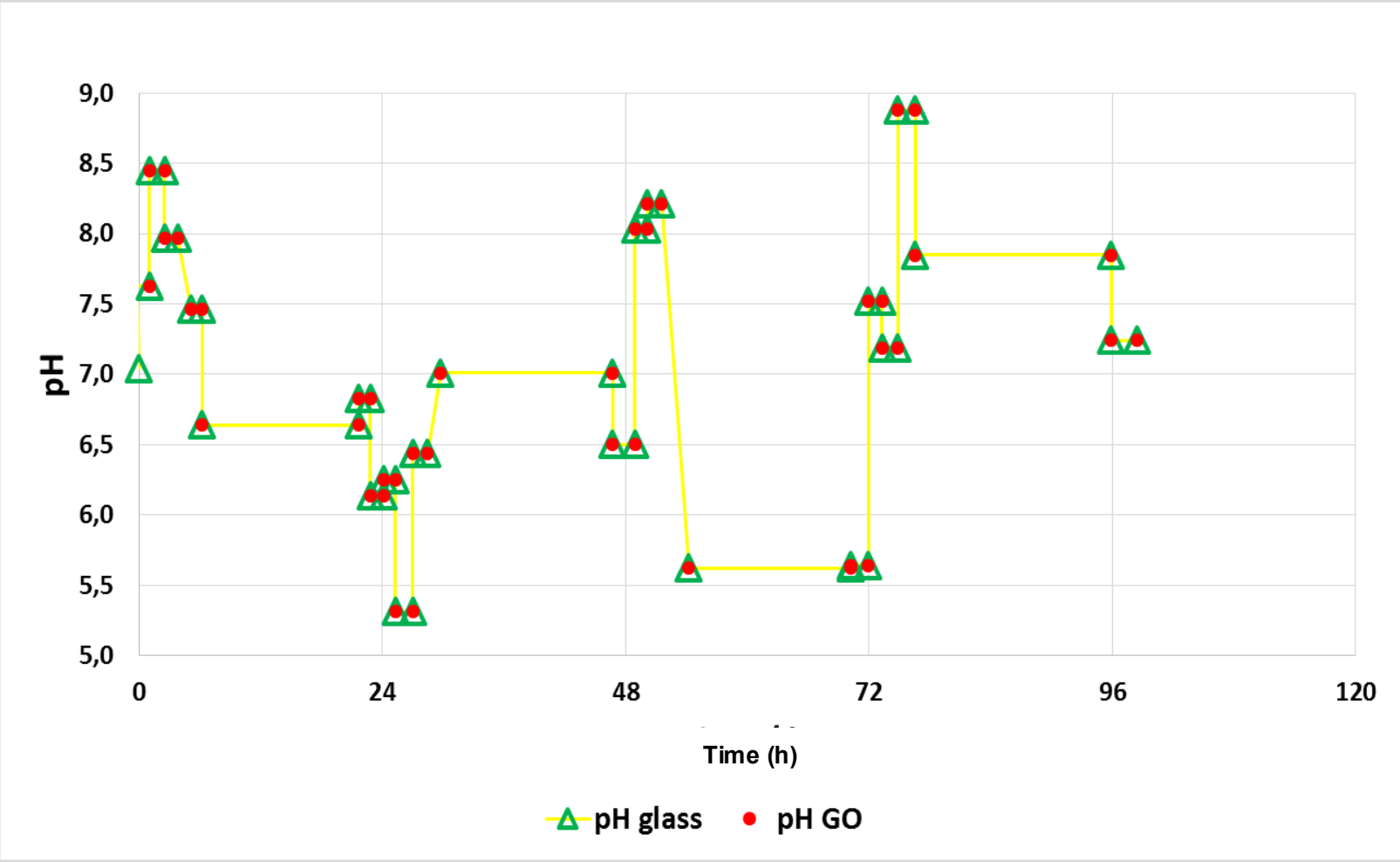
Test in human serum



Comparison between an rGO sensor and a thermistor in human serum at 30 and 45 °C

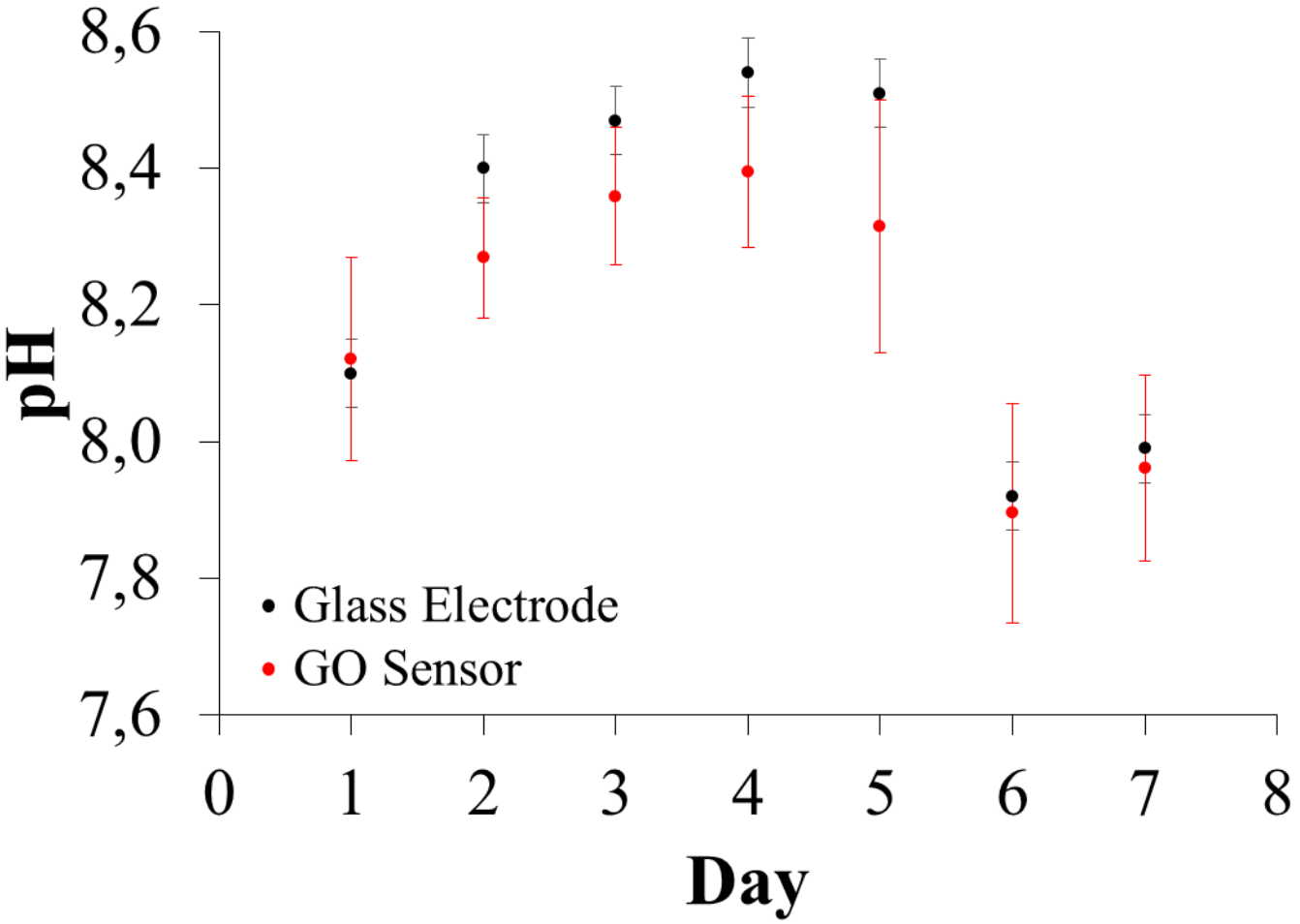
[1]P. Salvo et al. Temperature and pH sensors based on graphene-like materials for monitoring chronic wounds, submitted to Biosensors & Bioelectronics

GO sensor vs glass electrode over time



Test in Hank's buffer salt solution

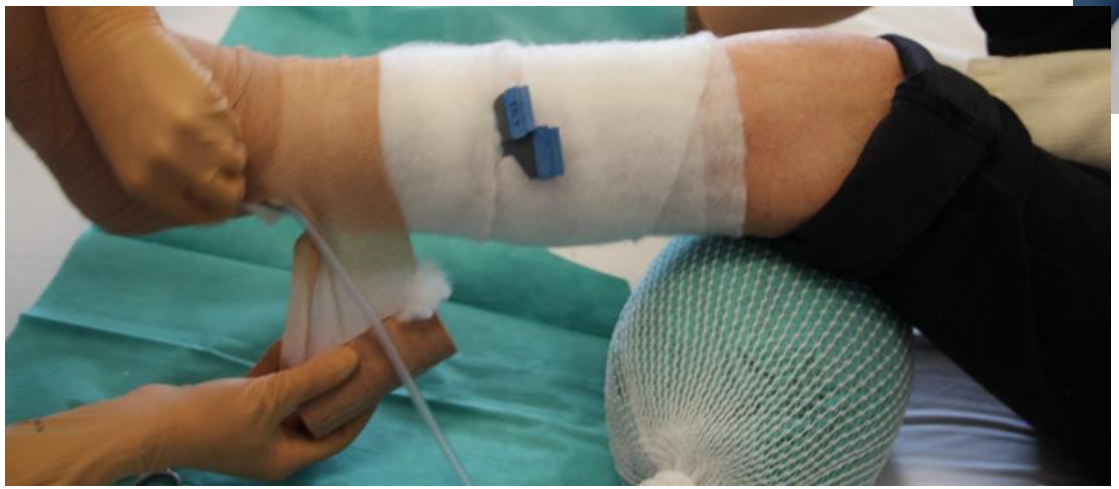
pH measurements in wound exudate



Minor deviations (0,2 pH units) from a reference glass electrode over one month

pH and Temperature evaluation

Application of the SWAN-iCare system



SWAN-ICARE SYSTEM

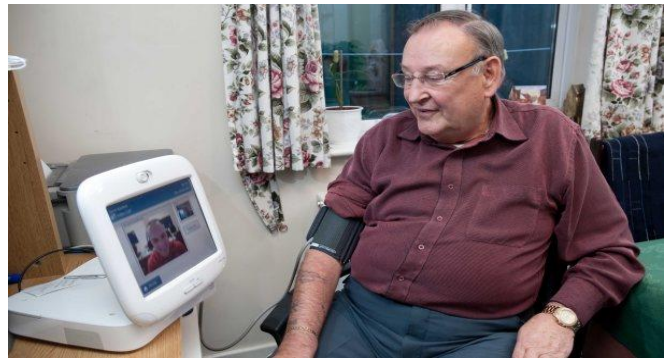
- Development of system focus:
  - 3 sensors
    - pH, temperature and MMP
  - 3 sub-systems :
    - In Wound Sensor Device (IWSD)
    - Smart Negative Pressure Device (SNPD)
    - Clinical back end

Expected Impact: the patient

Benefits for the patient

- Continuous home monitoring of a number of wound parameters
- Personalised therapy initiated by the physician remotely and adapted to the daily measurements
- Faster wound healing due to the early identification of potential problems

- Wound deterioration can be identified early and acted upon, therefore leading to reduced morbidity and amputation rates
- Reduced disturbance to patients life and possible need for hospitalisation
- Better quality of life with better mobility, more comfort ,less stress



Expected Impact: Society and Healthcare

Benefits for society and healthcare

- Reduced healthcare costs as a result of reduced need for hospitalization
- Reduced burden for the patients relatives due to faster wound healing and remote monitoring
- Reduced social costs and improved productivity as the patient returns to work earlier

- Increased access to best practice wound care for patients living in remote geographical locations
- Reduced daily nursing visits allows for more new patients' to be added to the case load

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SWAN iCare

Conclusions

- Disposable temperature and pH sensors are required to monitor chronic wounds
- The SWAN-iCare project aims at coupling negative pressure therapy and monitoring of wound conditions
- Graphene oxide dispersions in water can be used to prepare pH sensitive films and disposable pH sensors
- Reduced graphene oxide shows an almost linear dependence of electrical resistivity from temperature
- **Sensor materials are biocompatible and can be used in contact with the wound bed**
- These sensors show a good stability over time

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- Agata Janowska
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IN COOPERATION WITH

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FONDAZIONE PISA

SWAN iCare

SEVENTH FRAMEWORK PROGRAMME

European Commission

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Financial support of the EU Commission, contract n° 317894

If you want to run fast ,run alone

If you want to run far, run together….

www.sirtes.it

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