

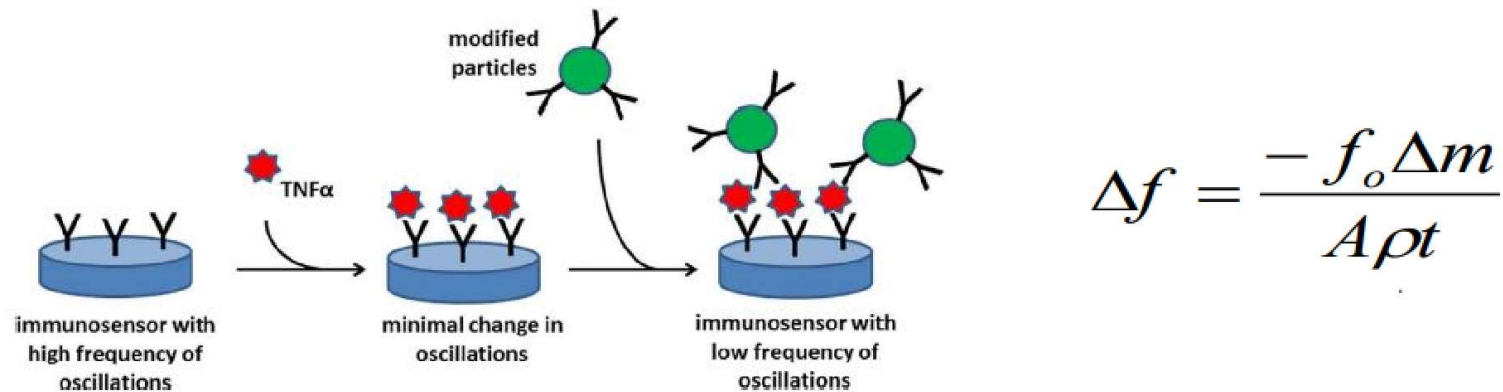
# Piezoelectric applications

Group activity

N.B. Da sapere per l'esame: applicazione 1 (microbilancia), 3 (batteria impiantabile) , 5 (patch dermico)

## Piezoelectric biosensor for the determination of Tumor Necrosis Factor Alpha (TNF $\alpha$ )

- Quartz Crystal Microbalance (QCM) is a detection system for blood concentration of TNF $\alpha$ , which is a crucial marker for various pathological conditions.
- The sensor is composed by a quartz layer on which specific antibodies for the analyte are immobilized. The system is placed in the solution containing TNF $\alpha$  and its oscillation is obtained exploiting the inverse piezoelectric effect. The antigen-antibody bond induces a mass increase with consequent variation of the oscillation frequency. Since the intrinsic piezoelectric sensitivity is insufficient to detect typical TNF $\alpha$  concentrations ( $\mu\text{g/ml}$ ), the analyte is marked with modified particles that increase the mass gain.



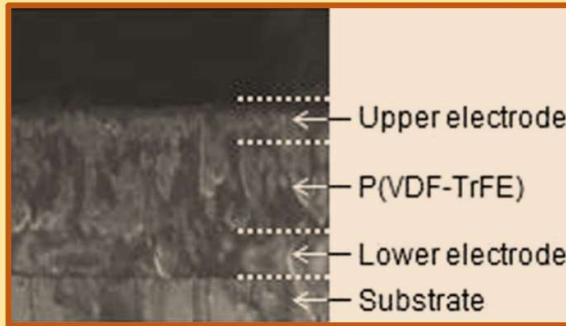
- This assay provides results as reliable as those of the already existing ones, through a faster and easier procedure.



# SENSORE INDOSSABILE OTTENUTO CON POLIMERO FERROELETTRICO PER MONITORAGGIO DEL RITMO CARDIACO

## REALIZZAZIONE DEL SENSORE:

- Substrato in PEN (Polietilene naftalato)
- Elettrodo inferiore in PEDOT:PSS
- Strato di P(VDF-TrFE)
- Elettrodo superiore in PEDOT:PSS

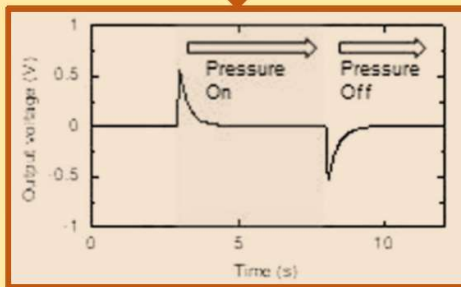


## CARATTERISTICHE DEL SENSORE:

- Compattezza (area = 4 mm<sup>2</sup>)
- Spessore = 3 μm
- Flessibilità e compatibilità con la pelle
- Sensibilità alle alte pressioni (0.025-1.5 MPa)
- Breve tempo di risposta (0.2 s)
- Buona stabilità meccanica e chimica

## RISPOSTA PIEZOELETTRICA

Il P(VDF-TrFE) genera picchi di tensione in risposta alla pressione: dipendenza lineare tra tensione e pressione applicata



## MONITORAGGIO PRESSIONE SANGUIGNA

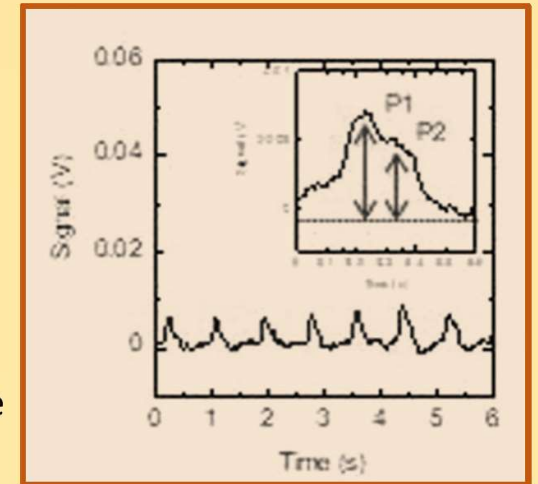
Utilizzo in ambito medico come rilevatore di patologie cardiovascolari.

Stima della rigidità dei vasi sanguigni come aumento del raggio.

$$AI (\%) = \frac{P2}{P1} \times 100.$$

P2=picco dell'onda corrispondente alla diastole

P1=picco dell'onda corrispondente alla sistole



**PROBLEMI  
DISPOSITIVI  
IMPIANTABILI:**

-Tempo limitato batteria

-Converte l'energia biomeccanica del movimento cardiaco nel corpo umano per alimentare in modo sostenibile i dispositivi impiantabili

-La tensione di uscita può arrivare a 3V

-eccellente flessibilità (considerata la morbidezza del tessuto biologico)

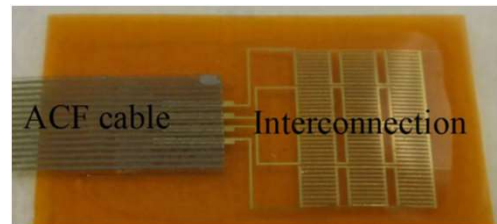


Rischi potenzialmente mortali



POSSIBILE SOLUZIONE

*DISPOSITIVO  
PIEZOELETTRICO  
ULTRA-FLESSIBILE (UFEH)  
BASATO SU PZT*

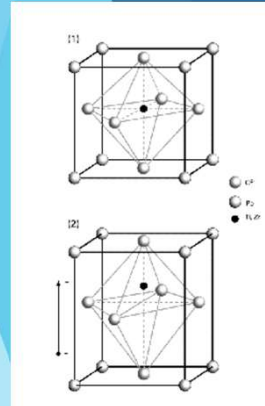


**FABBRICAZIONE:**

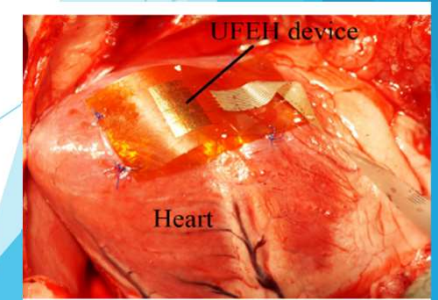
Processo fotolitografico standard  
Stampa transfer

**CARATTERISTICHE PZT:**

- Elevato coeff. piezoelettrico
- Elevata costante piezoelettrica

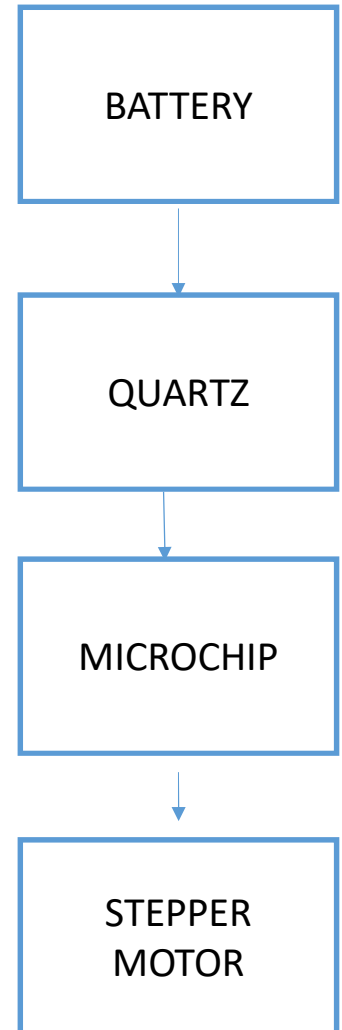
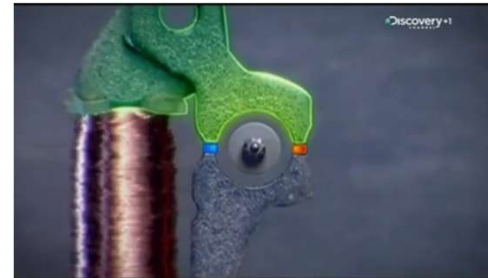


Test in vivo su miocardio suino



# The application of piezoelectricity to watches

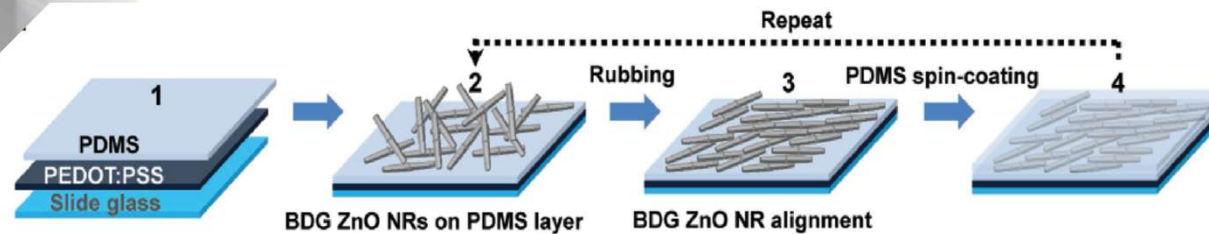
- The resonator circuit produces an electrical signal at a certain frequency and sends it to the Quartz crystal capsule. Quartz crystal begins to vibrate and produces electric current.
- It resonates with a frequency of 32768 Hz., 15 quartz vibrations correspond to a complete revolution of the rotor (two steps that mean one second).
- $2^{15} = 32.768$
- It is extremely stable and the time error is calculated in the order of sec/year.



# PIEZOELECTRIC DERMAL PATCH FOR WOUND HEALING



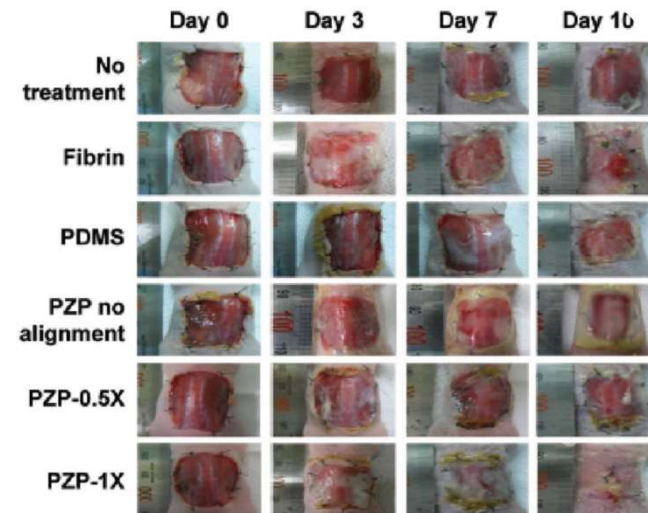
One-directionally aligned zinc oxide nanorod-based piezoelectric patch generates piezoelectric potential upon mechanical deformations induced by animal motion.



Electrical field induced at the wound bed promotes the wound healing process through enhanced cellular metabolism, migration, and protein synthesis.

## Limitations:

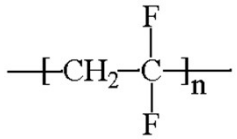
- the therapeutic effects of the piezoelectric patch can vary depending on the age, wound type, wound site and wound size of the patients;
- patches cannot be applied in immobile, static skin wounds.



'Zinc Oxide Nanorod-Based Piezoelectric Dermal Patch For Wound Healing', *S. H. Bhang, W. S. Jang, J. Han, J. Yoon, W. La, E. Lee, Y. S. Kim, J. Shin, T. Lee, H. K. Baik, B. Kim, Adv. Funct. Mater.* **2017**, 27, 1603497.

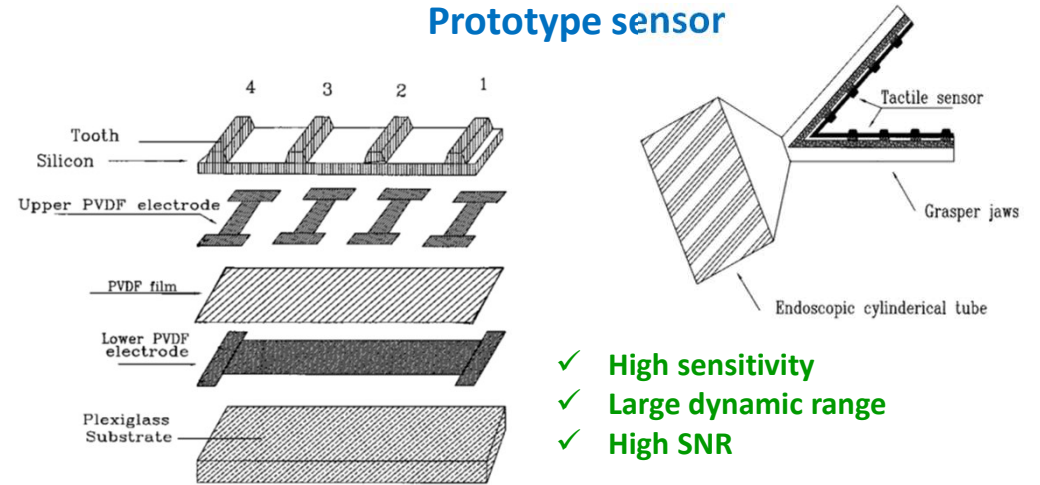
# PVDF piezoelectric material as a tactile sensor for endoscopic graspers

## PVDF



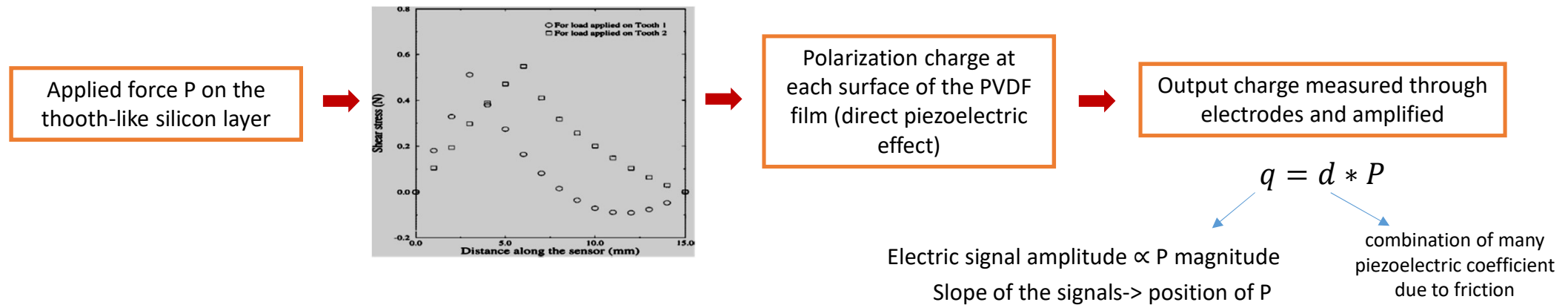
- Thermoplastic fluoropolymer
- Ferroelectric → poling
- 6 μm to 2-mm thick, flexible → film easily conformed to complex surfaces (e.g. design of sensitive tactile sensors)
- Large electronegativity of Fluorine atoms vs carbon atoms → strong piezoelectric coeff

## Prototype sensor



- ✓ High sensitivity
- ✓ Large dynamic range
- ✓ High SNR

## Process pipeline

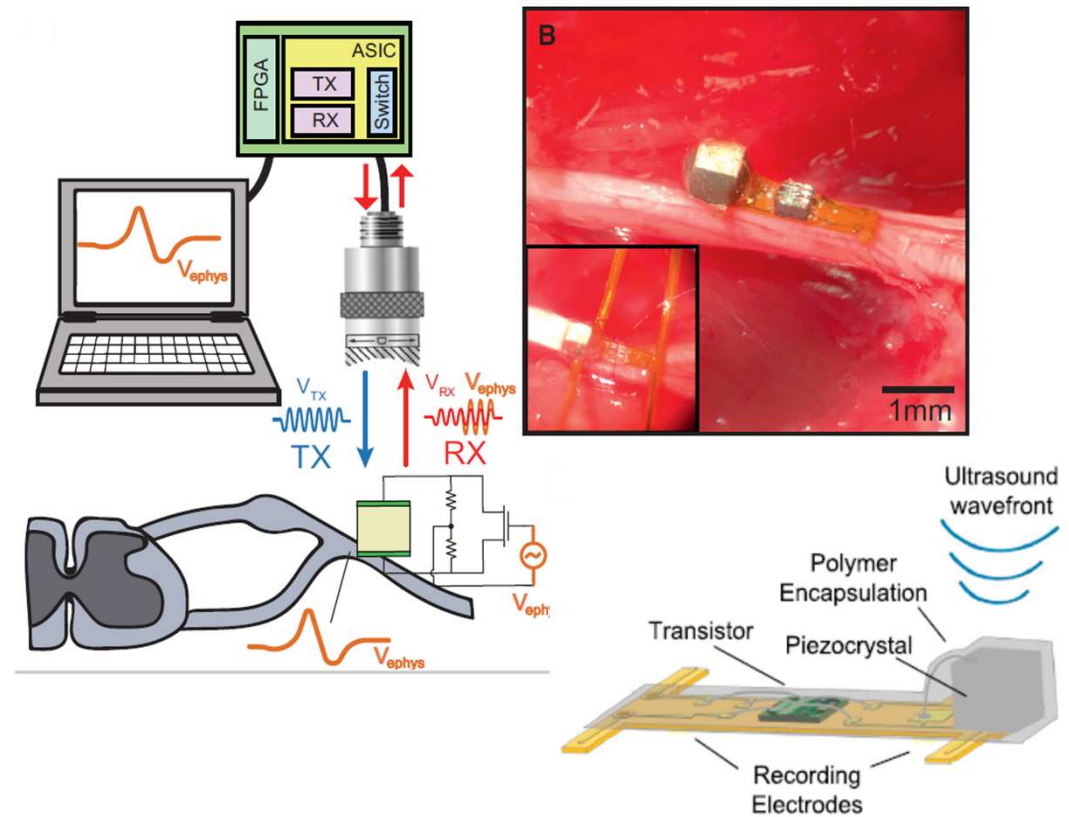


# ULTRASONIC NEURAL DUST

*First in vivo electrophysiological recordings with neural dust motes. Passive, wireless, and battery-less EMG and ENG recording with mm-scale devices.*

*The neural dust system consists of an external ultrasonic transceiver board which powers and communicates with a millimeter-scale sensor implanted into either a nerve or muscle. The implanted mote consists of a piezoelectric crystal (biocompatible BaTiO<sub>3</sub>), a single custom transistor, and a pair of recording electrodes.*

- *Lower attenuation and greater penetration than EM radiation*
- *Significantly decreases the amount of unwanted power introduced into tissue due to scattering or absorption*
- *Neural dust present greater noise floor comparison to other state-of-the-art systems*



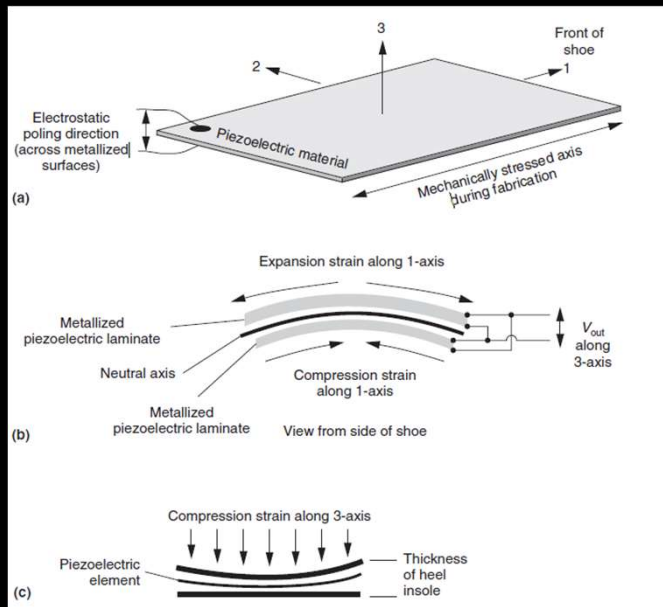
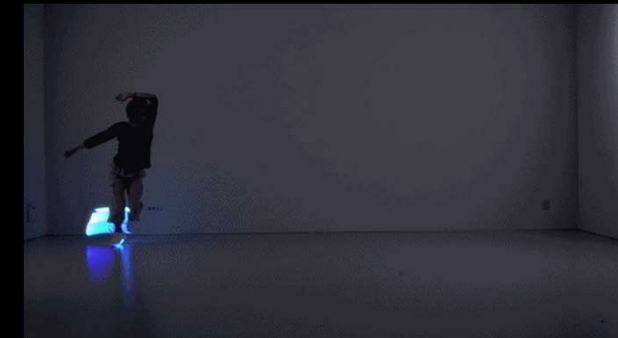
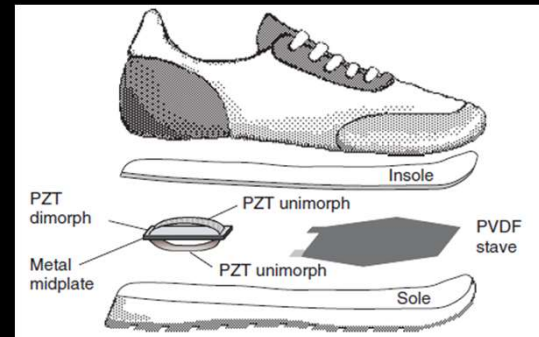


# POWER HARVESTING WITH SHOE-MOUNTED PIEZOELECTRICS

## IL FASCINO DEL «WEARABLE»: ENGINEERING AND FASHION

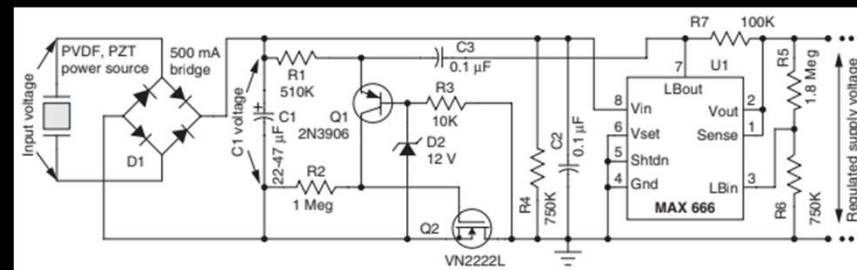
### MATERIALI E METODI

- **Multilayer Laminate PVDF foil piezoelectric:** struttura con due strati di PVDF e al centro uno strato di plastica flessibile. Quando viene piegata, i fogli esterni di PVDF si espandono e quelli interni si contraggono, producendo una tensione ai capi degli elettrodi posizionati sui fogli;
- **Dimorph strip made from piezoceramic composite material:** striscia dimorfa di acciaio armónico legato a materiale piezoceramico modificato in modo da essere molto flessibile. Sfrutta l'energia impulsiva che si genera nella zona del tacco durante la camminata;



### FUNZIONAMENTO

Durante il passo viene indotta la deformazione della suola e, per effetto piezoelettrico diretto, viene registrata la variazione di tensione ai capi degli elettrodi, collegati al sistema. Il segnale in uscita subisce processi di rettificazione e regolazione mediante un apposito circuito.



### APPLICAZIONI

- Cercapersone
- Health monitor (ad es. Contapassi, monitoraggio del movimento negli atleti)
- Ricevitori di emergenza
- Tag per identificazione mediante radiofrequenza in caso di lunghe escursioni o missioni militari (per sistemi di localizzazione per militari, unità di polizia)
- Luci di emergenza
- Altri sistemi elettronici indossabili

### RIFERIMENTI

- J. Kymissis et al., "Parasitic Power Harvesting in Shoes," *Second IEEE Int'l Conf. Wearable Computing*, IEEE CS Press, Los Alamitos, Calif., 1998, pp. 132-139.
- N. S. Shenck and J. A. Paradiso, "Energy scavenging with shoe-mounted piezoelectrics," in *IEEE Micro*, vol. 21, no. 3, pp. 30-42, May/June 2001.