3D graphene foam energy-autonomous TENG sensors for Internet of Things sensing devices.

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Introduction

Nowadays, internet of Things (IoT) reach billions of electronic devices utilised in different sectors including health care/monitoring, mobile devices, navigation, automobiles, smart buildings, and manufacturing industry.

The high cost of electricity and incremental energy demand from IoT devices require: new green energy sources, high efficiency harvesting & storing systems and low-power consumption (or even self-powered) sensors. [1]

Future smart buildings will monitor temperature, noise, CO_2, humidity and occupancy through IoT sensors to optimise the efficient use of electricity, leading to a reduction of carbon footprint and fostering a more sustainable technology. [2]

Triboelectric nanogenerators (TENG) a promising energy harvesting technology that takes mechanical energy wasted in the environment to power such IoT technology. [3]

Triboelectric Nanogenerators (TENG)

1. Triboelectric interface is formed.
2. The potential difference moves charges, creating an electric current.
3. Equilibrium is reached when the two surfaces are fully separated.
4. The electrostatic induced charges flow back to compensate for electric potential difference.

TENG materials
- Cu (electrode)
- Tribopositive film (+)
- Tribonegative film (-)
- ITO (electrode)

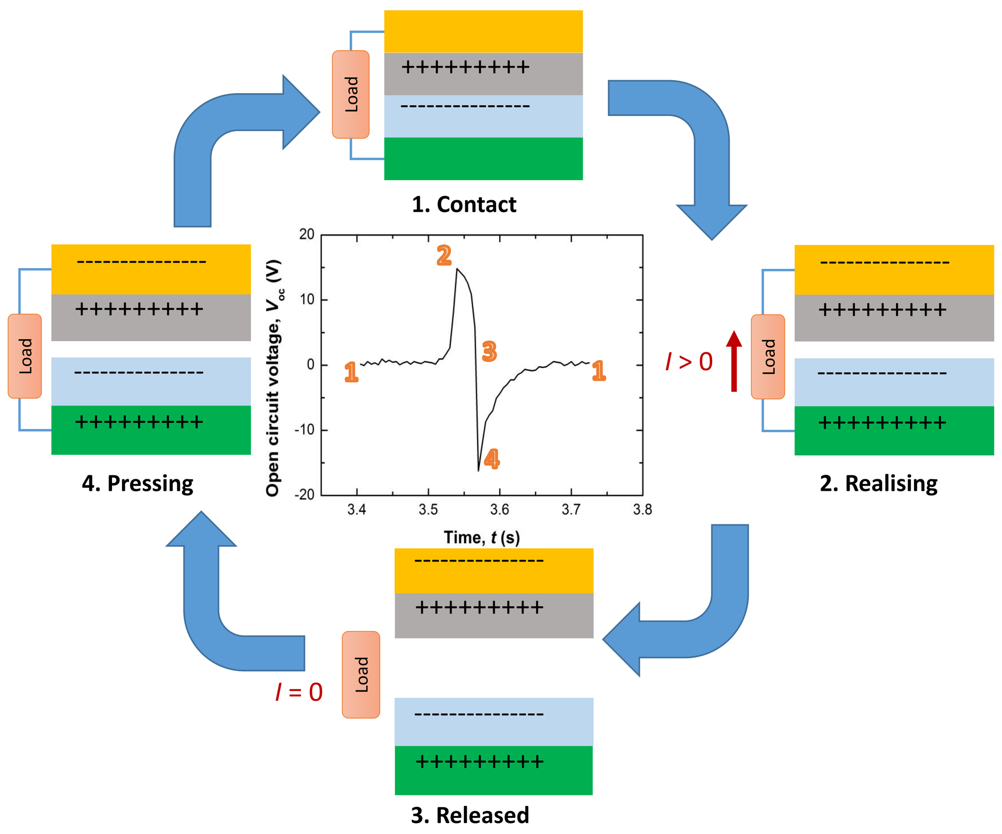
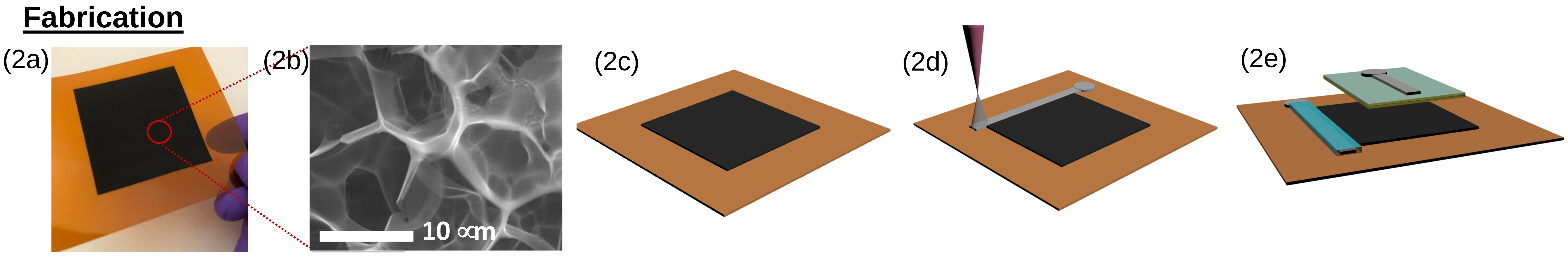


Figure 1: Shows the monition of TENG in contact-separation mode. [3]

Our Research

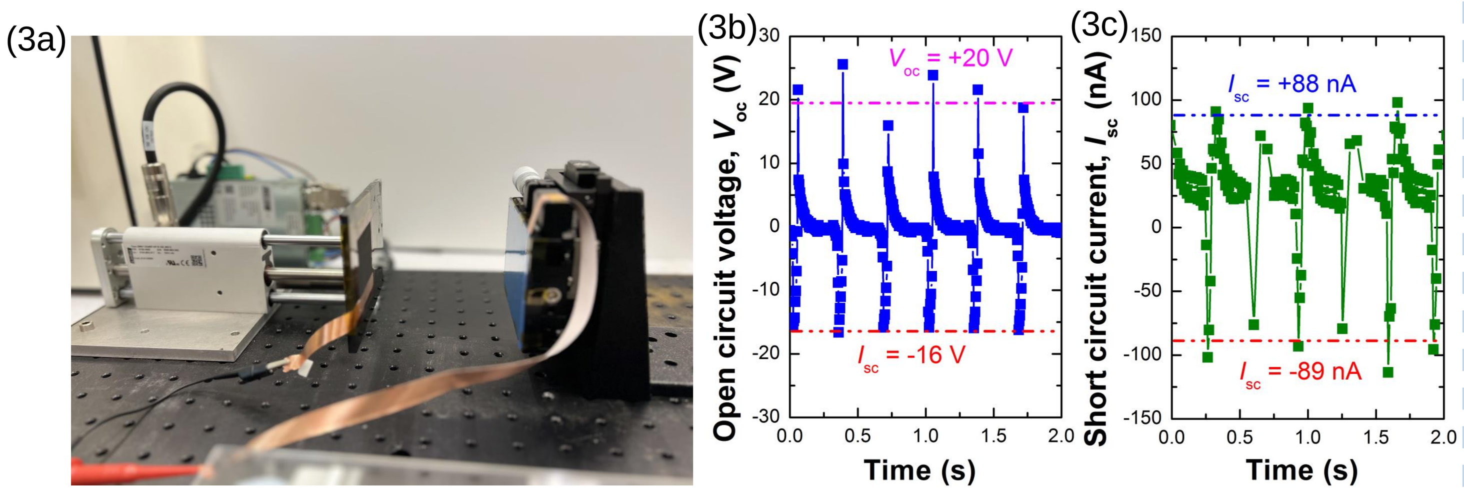
Fabrication



Materials summary
- 3DG foam
- PI
- ITO
- Ag electrode
- Protective layer
- PET

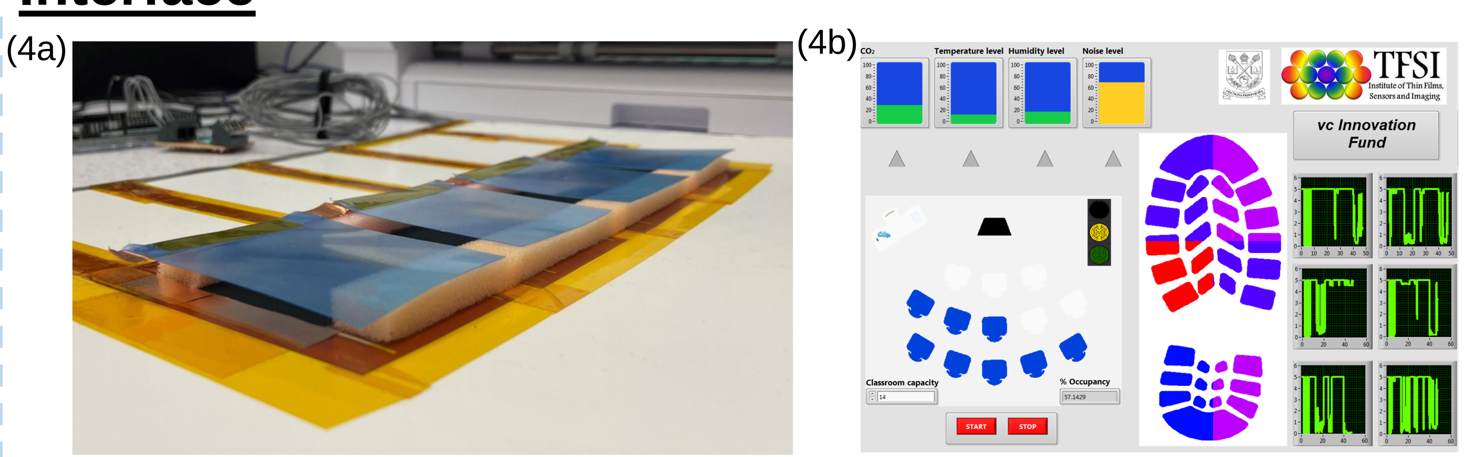
Figure 2: 3D graphene foam (3DG) (2a) also known as Gii^{TM} is grown using a method patented by Integrated Graphene Ltd. (2b) SEM image presenting the porous structure of 3DG. This revolutionary method allows us to deposit 3DG on flexible substrates (2a,2c). Ag electrodes were inkjet-printed on 3DG. (2e) Diagram presenting TENG materials, 3DG an electropositive material (top) and PET (Polyethylene terephthalate) an electronegative material (bottom).

Methodology



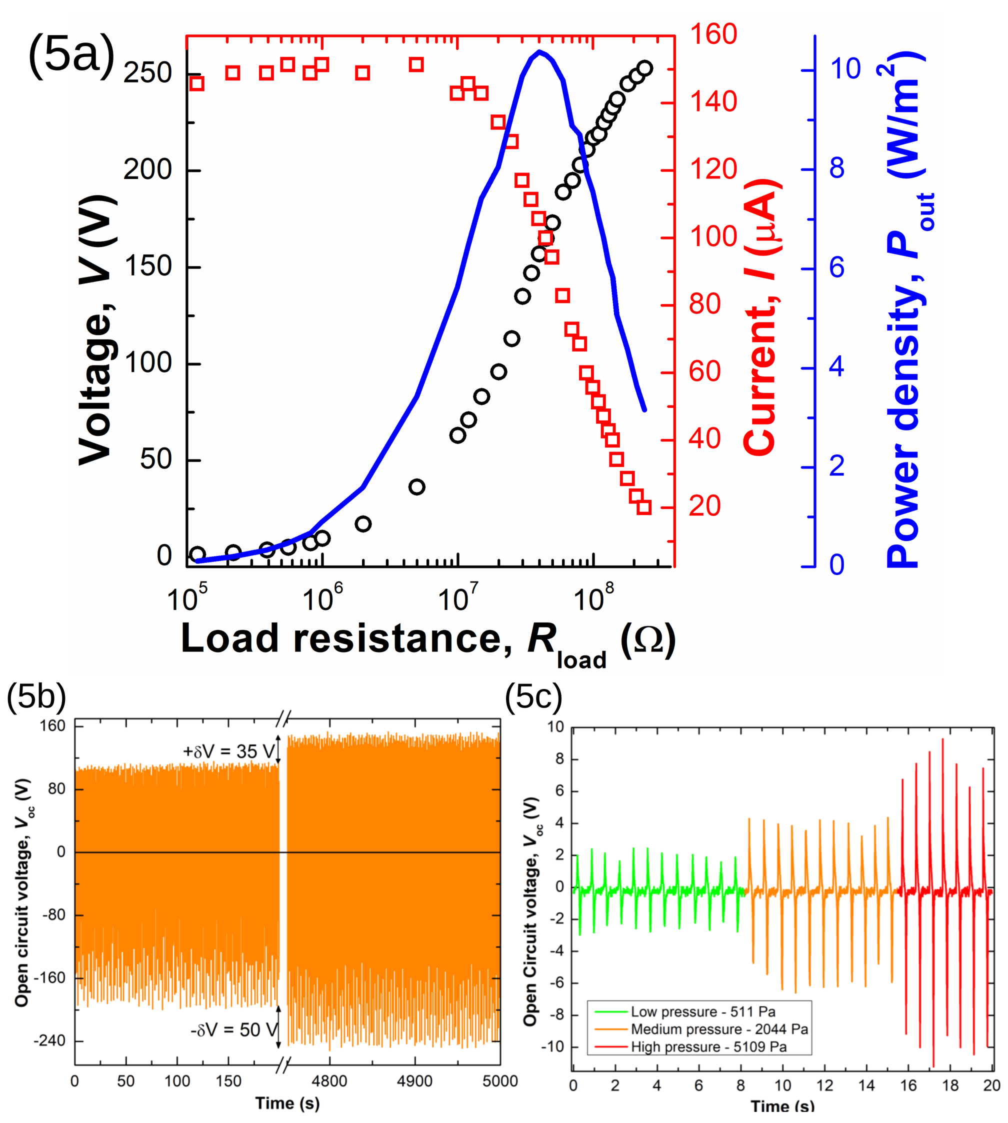
- Figure (3a) shows linear motor holding graphene and a fixed platform with the material PET.
- The linear motor was programmed to travel a fixed distance depended on measure the voltage measured by the change in speed, acceleration, and gap distance between the electrodes.
- Figure (3b) & (3c) are examples of V_{oc} and I_{sc} vs time produced by TENG in contact-separation mode.

Interface



- For the application, an array of TENG sensors have been assembled (4a) to anonymously monitor room occupancy.
- An example of this in figure (4b) shows a screenshot of a LabVIEW monitoring sensors readouts while recording the temperature, humidity and noise level relative to the number of people present in a classroom.
- Each pressure sensor was connected to the analog ports of an Arduino Nano.

Results and Discussion



- Demonstrates the successful use of 3DG as an electropositive material in TENG.
- Figure (5a) shows a high-power density of 10.37W/m^2.
- An optimal load resistance of 40MΩ, showing a low internal impedance.
- Figure (5b) shows high stability over 15k cycles with >95% retention.
- Figure (5c) shows the range in pressure the TENG sensor can produce.
- Energy-autonomous TENG pressure sensor mat.

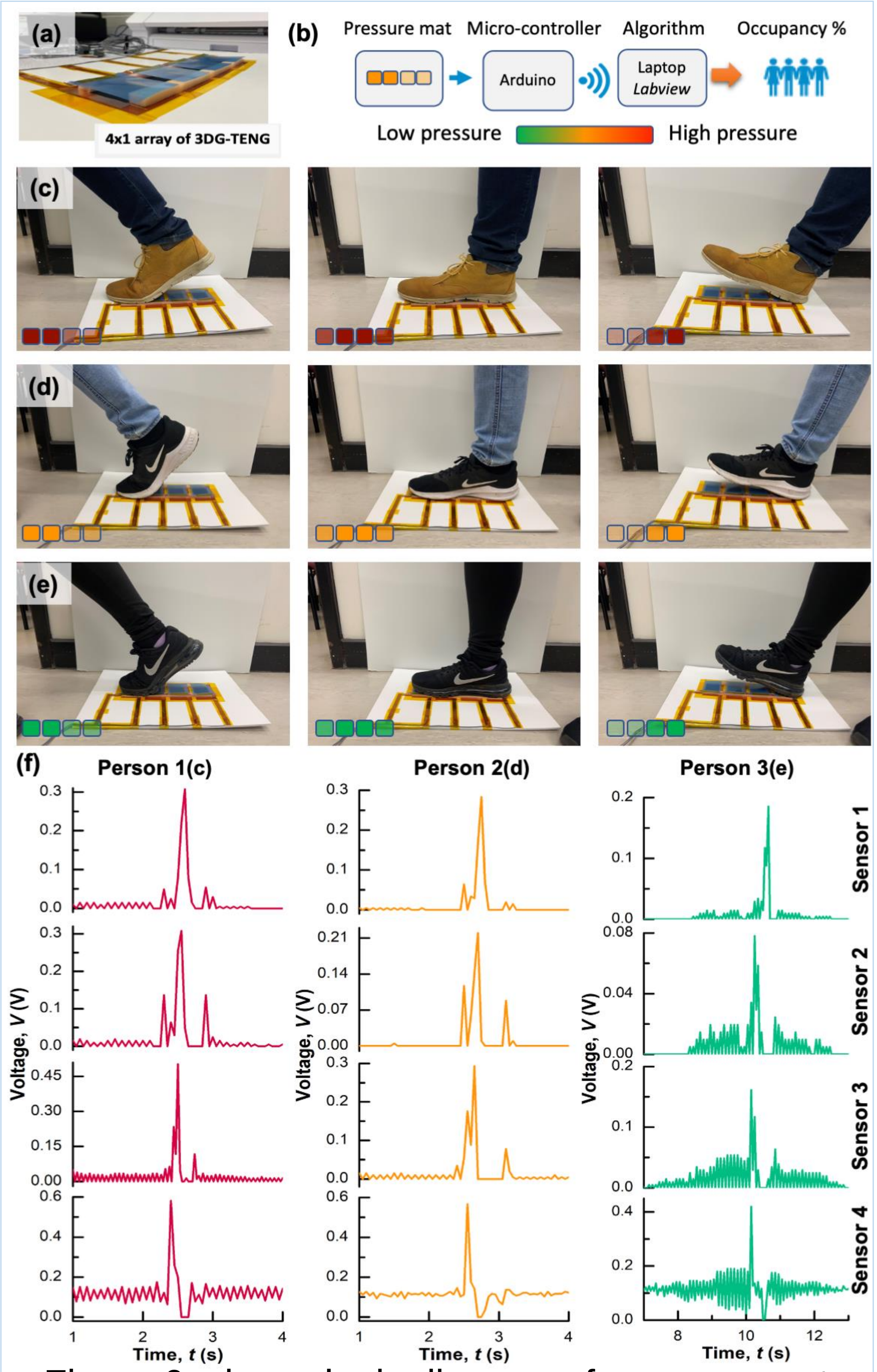


Figure 6: shows logic diagram of pressure mat, (c, d & e) shows people applying different pressure to mat, (f) shows a voltage produced by each individual.

References

1.Qiu, Chunkai, et al.." *Nano Energy* 70 (2020): 104456.
2.García Núñez, Carlos, et al. *npj Flexible Electronics* 3.1 (2019)
3.Keel, Emma, et al. *Nano Energy* (2023): 108475.

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