Porous PDMS conformable coating for high power output carbon fibers-based single electrode triboelectric energy harvesters

R. Barras*, A. dos Santos, E. Fortunato, R. Martins, H. Águas, P. Barquinha, R. Igreja, L. Pereira**

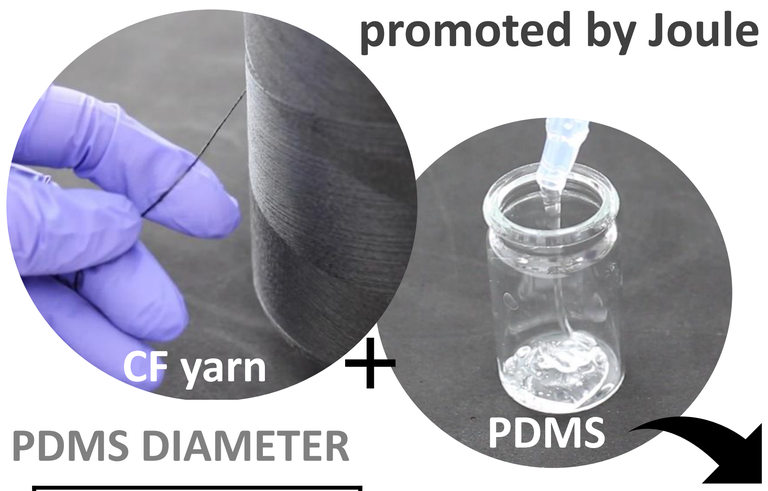
CENIMAT|i3N, Department of Materials Science, Nova School of Science and Technology, FCT-NOVA, Universidade Nova de Lisboa, Campus de Caparica, 2829-516 Caparica, Portugal

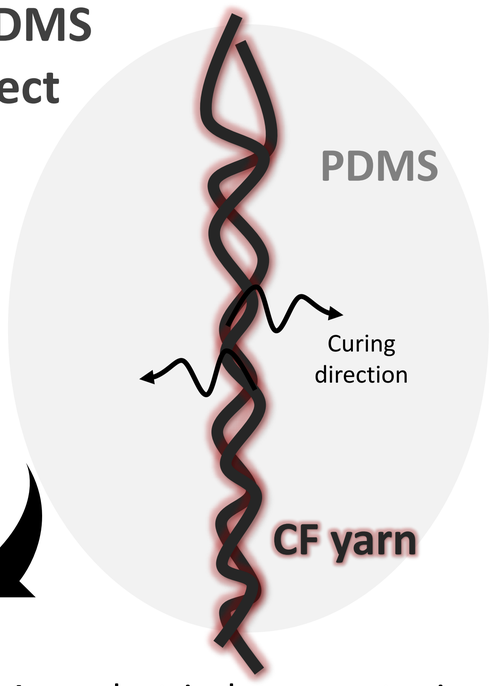
* r.barras@campus.fct.unl.pt ** lmnp@fct.unl.pt

ABSTRACT A new method for depositing PDMS directly onto conductive carbon yarns is proposed to produce Triboelectric Generator Yarns (TEG yarns). The in-situ PDMS curing method described in this study allows the fast formation of a uniform thick coating over conductive surfaces regardless of their roughness. Single-electrode configuration TEG yarns are developed, and their electrical output is optimized by precisely adjusting the PDMS layer thickness and by changing the chemical and physical nature of the carbon fiber (CF) yarns' surface. Functionalizing the CF yarns' surface with ZnO rods combined with porous PDMS coating can enhance their electrical output. The best results achieved using this type of TENG yarns with an average diameter of 1.74 mm, which can be obtained after only 3 min of PMDS deposition by "in-situ" curing method. A maximum of 72 V peak-to-peak and 10 µA (74.1 µW cm^{-2} of power density with a load resistance of 20 MΩ) is reached when applying an impact force of 600 N to a set of five TENG yarns connected in parallel. The output is stable even after 10,000 cycles and this set of TENG yarns is also able to light at least 28 LEDs when tapping by hand, proving a contribute towards the development of basic building blocks to power the future generation of wearables. In addition, electrophoretic deposition of nanocrystalline cellulose films on enhancing TEGs electrical output was also studied. A quantification of both tribo and piezoelectric phenomenon contribution for the final output was estimated.

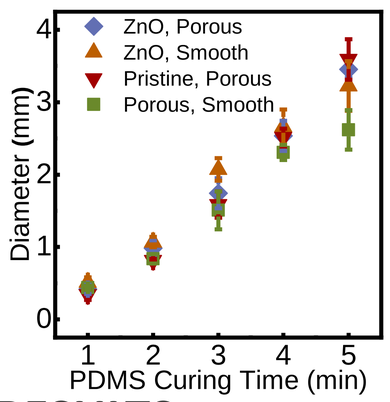
METHODS

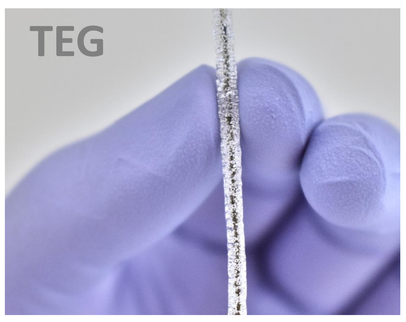
In-situ curing of PDMS promoted by Joule effect





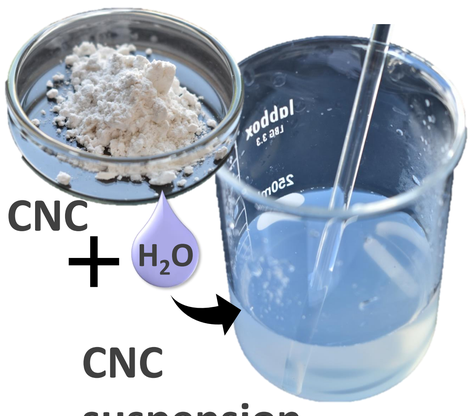
PDMS DIAMETER

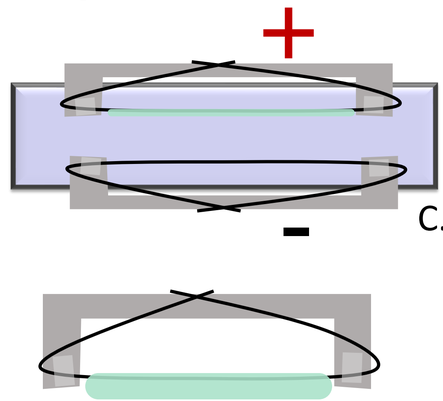




An electrical current is injected through the conductive CF yarn and heat dissipation cures PDMS locally and inside-out.

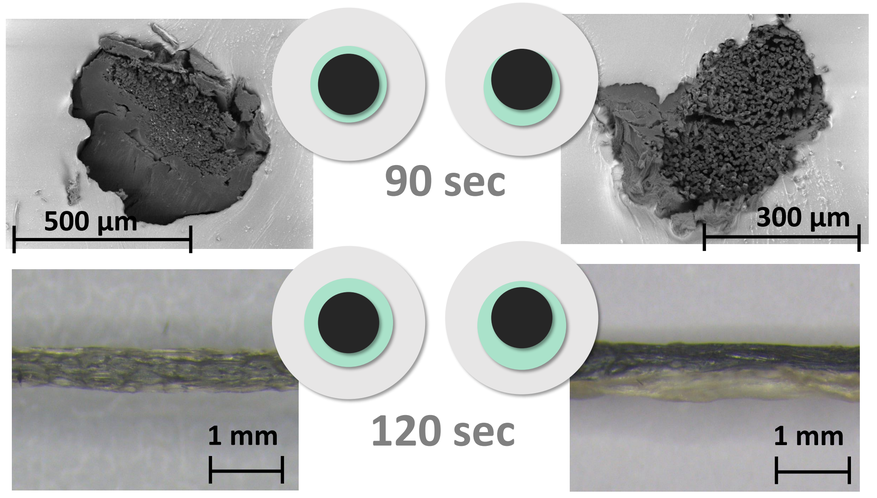
Electrophoretic deposition of Cellulose Nanocrystals





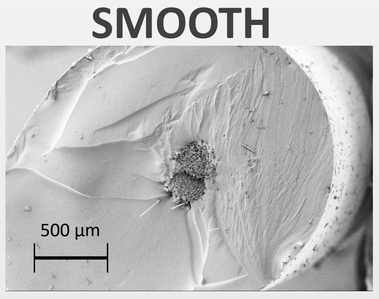
Asymmetric deposition of CNC due to forces of gravity

Assisted by rotation: **No rotation:**

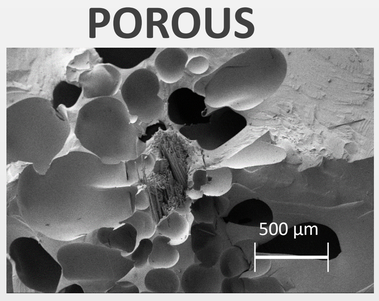


RESULTS

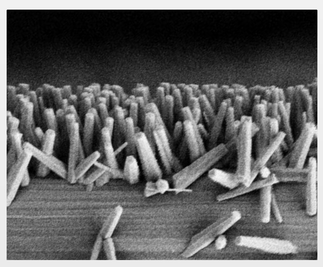
SMOOTH



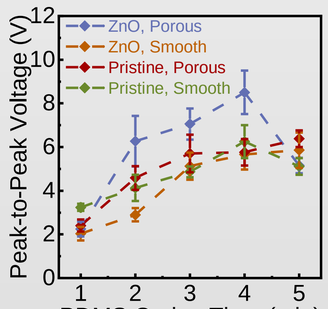
POROUS

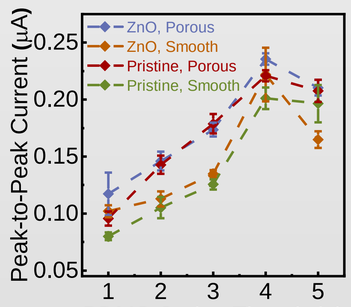


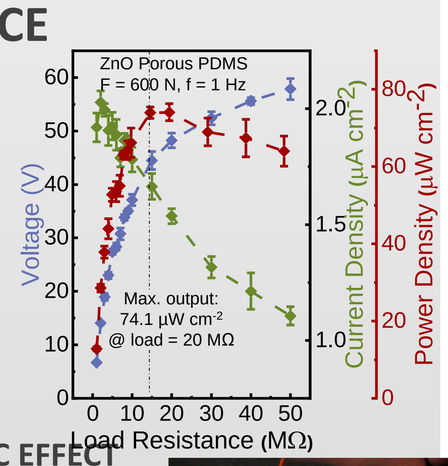
POROUS+ZnO



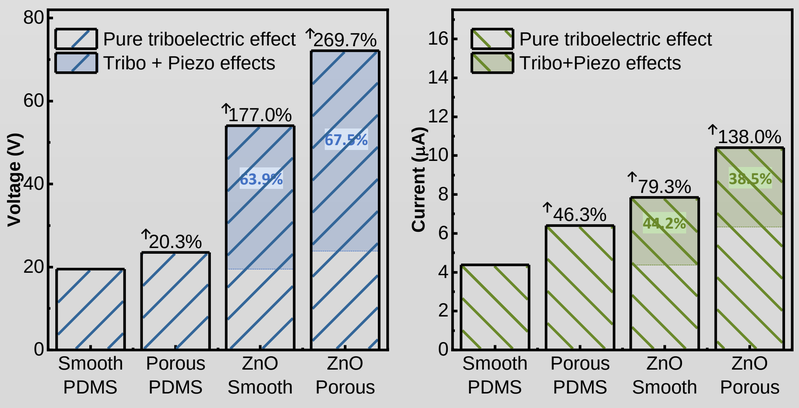
ELECTRICAL PERFORMANCE



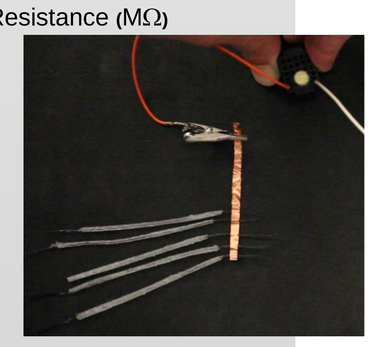


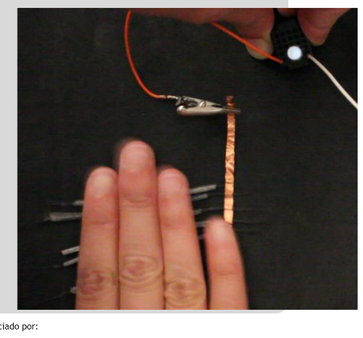


QUANTIFYING PIEZOELECTRIC & TRIBOELECTRIC EFFECT

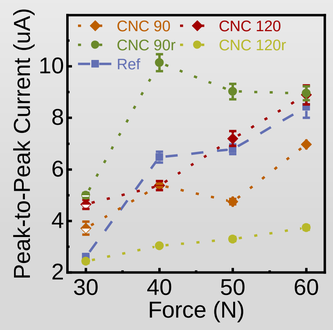


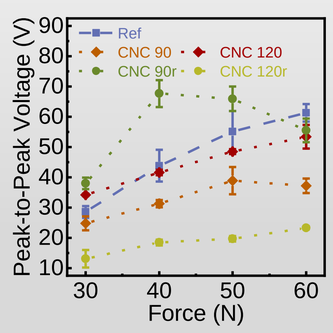
- From an overall increase of nearly **270 %** on output voltage, a maximum of **67.5%** can be assigned to **piezoelectric** phenomenon on generators made up of porous PDMS and ZnO rods.

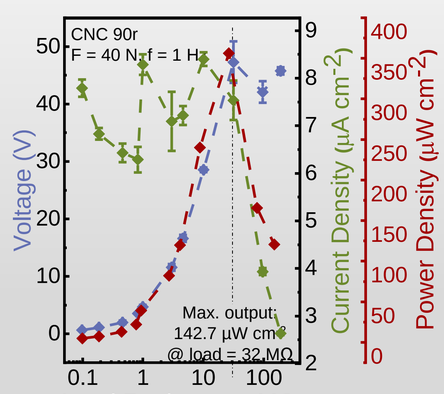




ELECTRICAL PERFORMANCE







CONCLUSIONS

- A new method to cure porous PDMS around fiber structures using localized Joule heating was studied and used to develop weavable fiber based power generators.
- High power triboelectric nanogenerators were achieved by controlling the thickness and porosity of the PDMS, and by adding a layer of aligned ZnO rods around carbon fiber yarn conductive electrode.
- TEGs with **porous PDMS and ZnO rods** and average **diameters of 1.7 mm** presents the best results: **V_{OC} of 72 V (Vpp)** and **I_{sc} of 10 µA (Ipp)** when force of impact is **600 N**. Output of generator **increases for larger forces** applied. A maximum **power density of 74.1 µW cm^{-2}** (using a 20 MΩ load resistance) is achieved for 600 N of force applied.
- TEGs with electrophoretic deposited CNC **without rotation for 90 sec** results in the asymmetric distribution of an isolating layer around the CF yarn and presents an increased power conversion of around of **142.7 µW cm^{-2}** (using a 32 MΩ load resistance), achieved for 40 N of force applied at 1 Hz.

More information available at:
R Barras et al, **Porous PDMS conformable coating for high power output carbon fibers/ZnO nanorod-based triboelectric energy harvesters**, Nano Energy Vol 9 B, 106582 , **2021 . DOI: 10.1016/j.nanoen.2021.106582**

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