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# Smart nanogenerators based on piezo-electrical polymer nanocomposites to develop a self-powered QRS (Quantum Resistive Sensor)

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## INTRODUCTION

Considering growth of the portable electronics and depletion of the fossil energy resources, the development of sustainable energy is extremely urgent [1]. **Smart nanogenerators** have been investigated for **harvesting energy** sources including solar, thermal or mechanical energy to make self-powered electronic systems which is a desired concept when developing wireless sensors, 5G or personal electronics [2]. Materials such as P(VDF-TrFe) and **nanocomposites** loaded with ceramics such as PZT or BaTiO<sub>3</sub> are commonly used [3]. SENSE IN is currently developing sensors for structural health monitoring. These embedded sensors can be used on composite structures such as wind turbines which undergo strong vibrations. In addition, sQRS sensors need few nW to work, and they could possibly be self-powered by nanogenerators.

## ENERGY HARVESTING THEORY

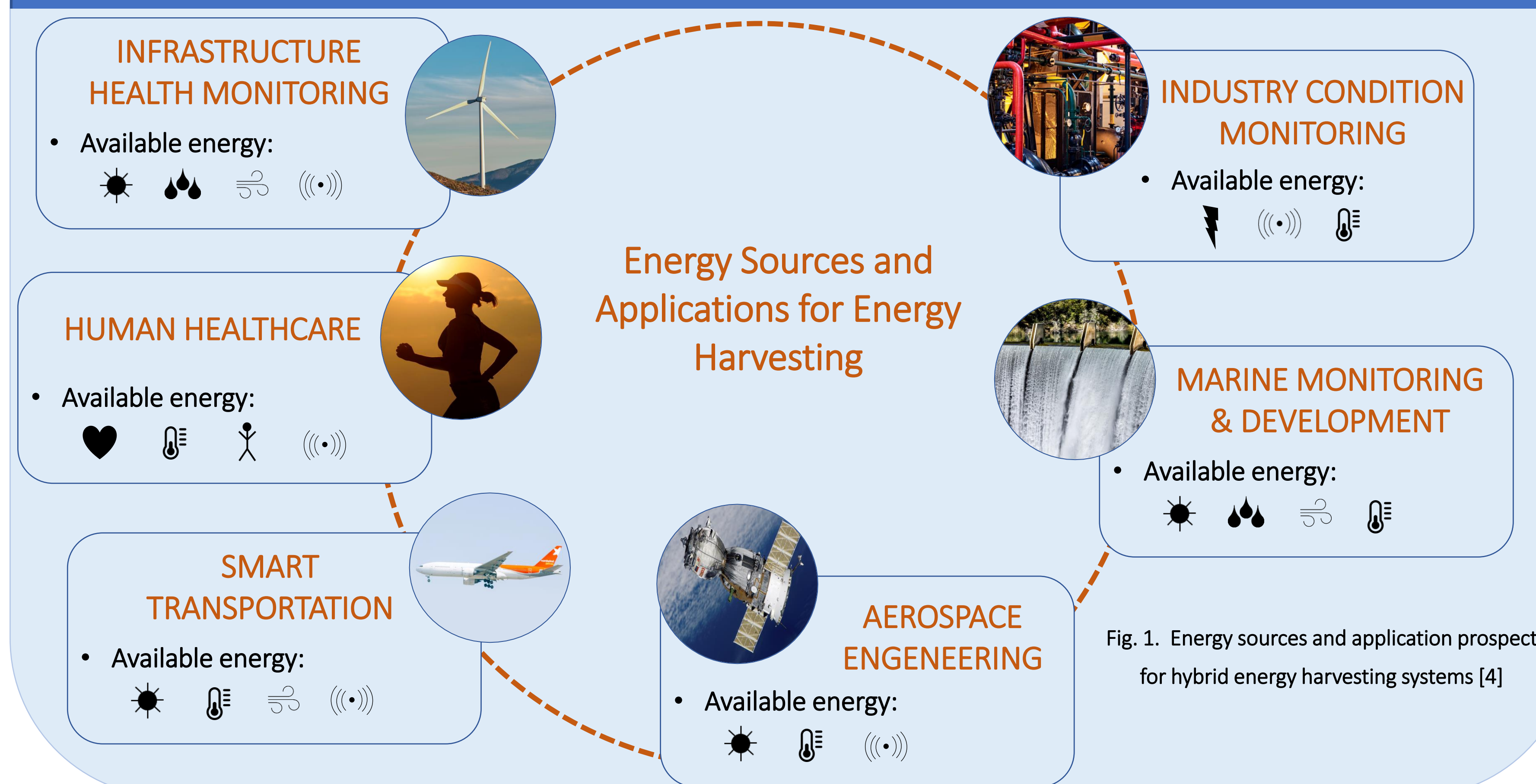


Fig. 1. Energy sources and application prospect for hybrid energy harvesting systems [4]

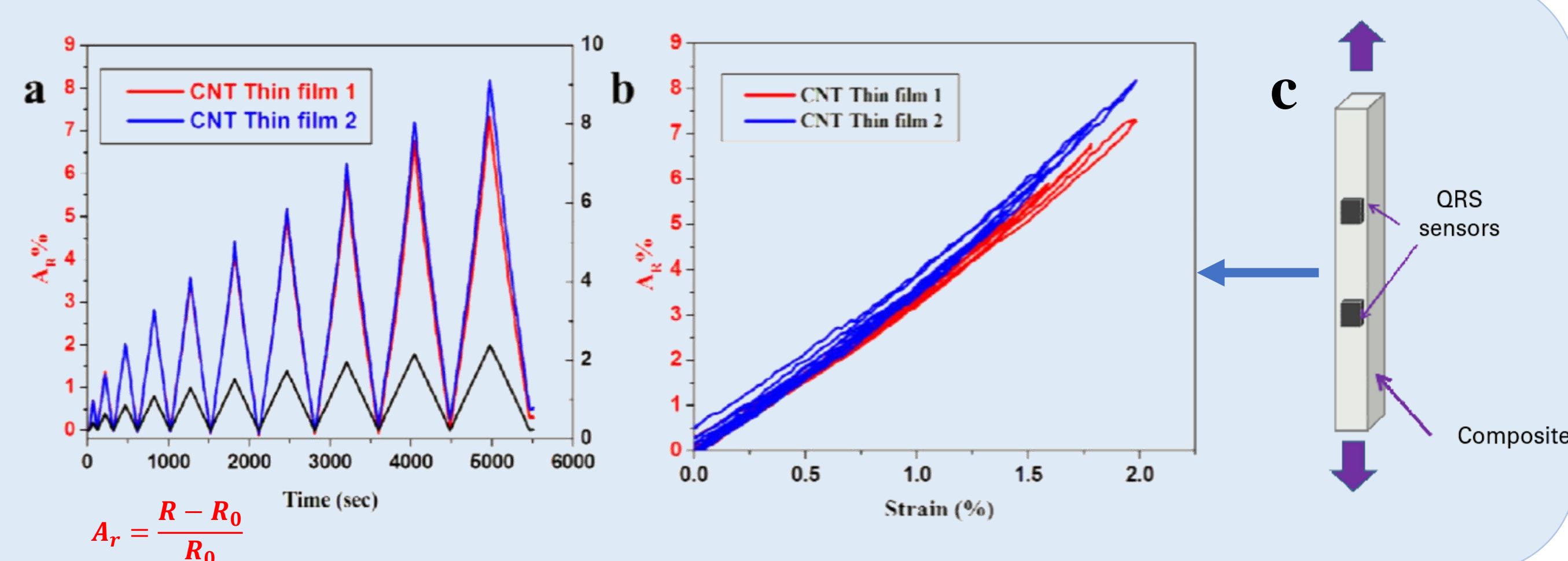


Fig. 2. (a) Simultaneous response of stress, strain, resistance change during incremental cyclic loading/unloading; (b) hysteresis curve of  $A_r$  vs deformation; (c) sQRS sensor solicitation [4].

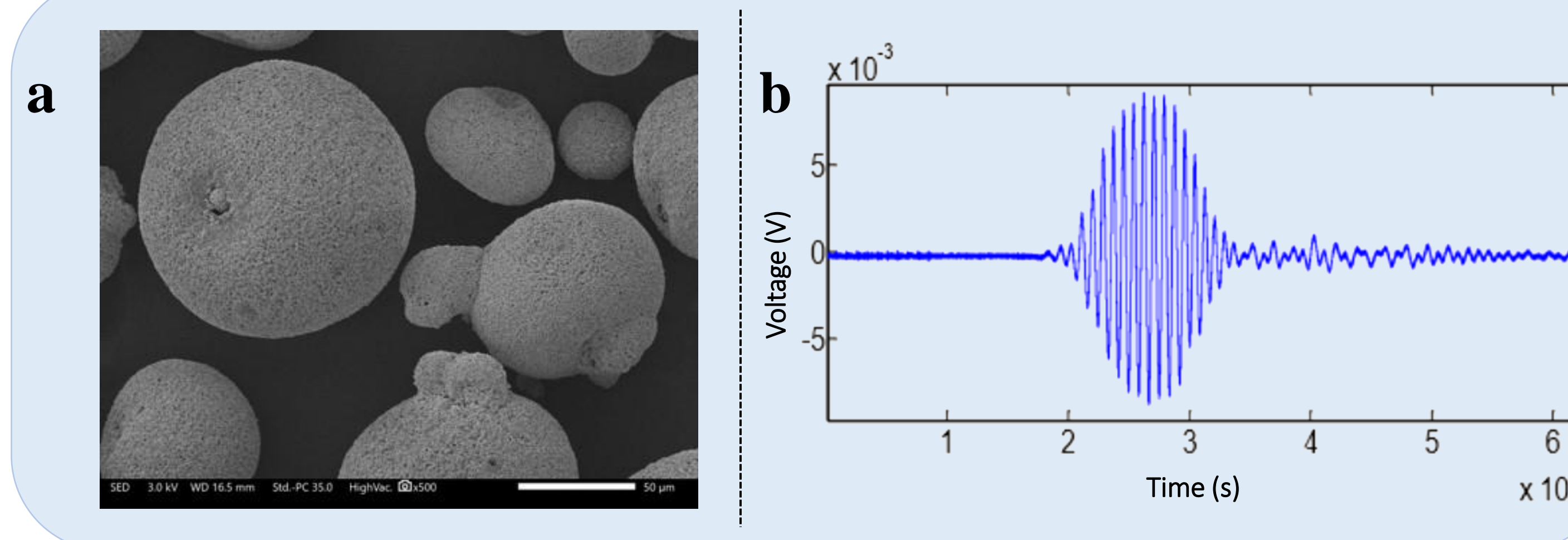


Fig. 3. (a) SEM photography of ceramics fillers; (b) Voltage generation during the detection of the surface wave generated by a flexibial sensor based on PZT [5].

QRS sensors could be power supplied by QPS (Quantum Piezoelectric System) for SHM

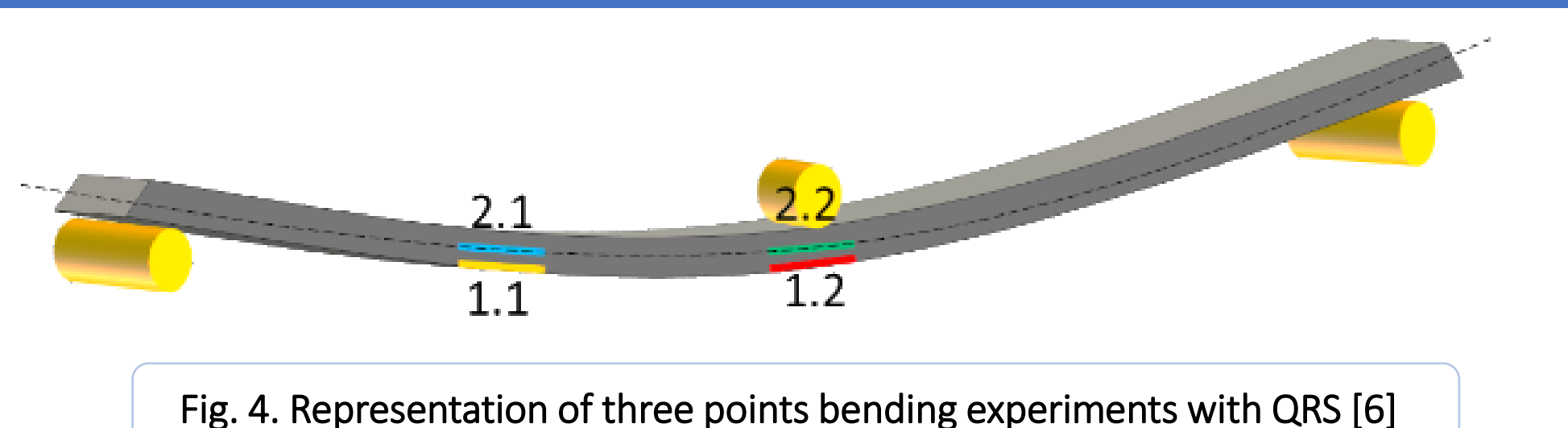


Fig. 4. Representation of three points bending experiments with QRS [6]

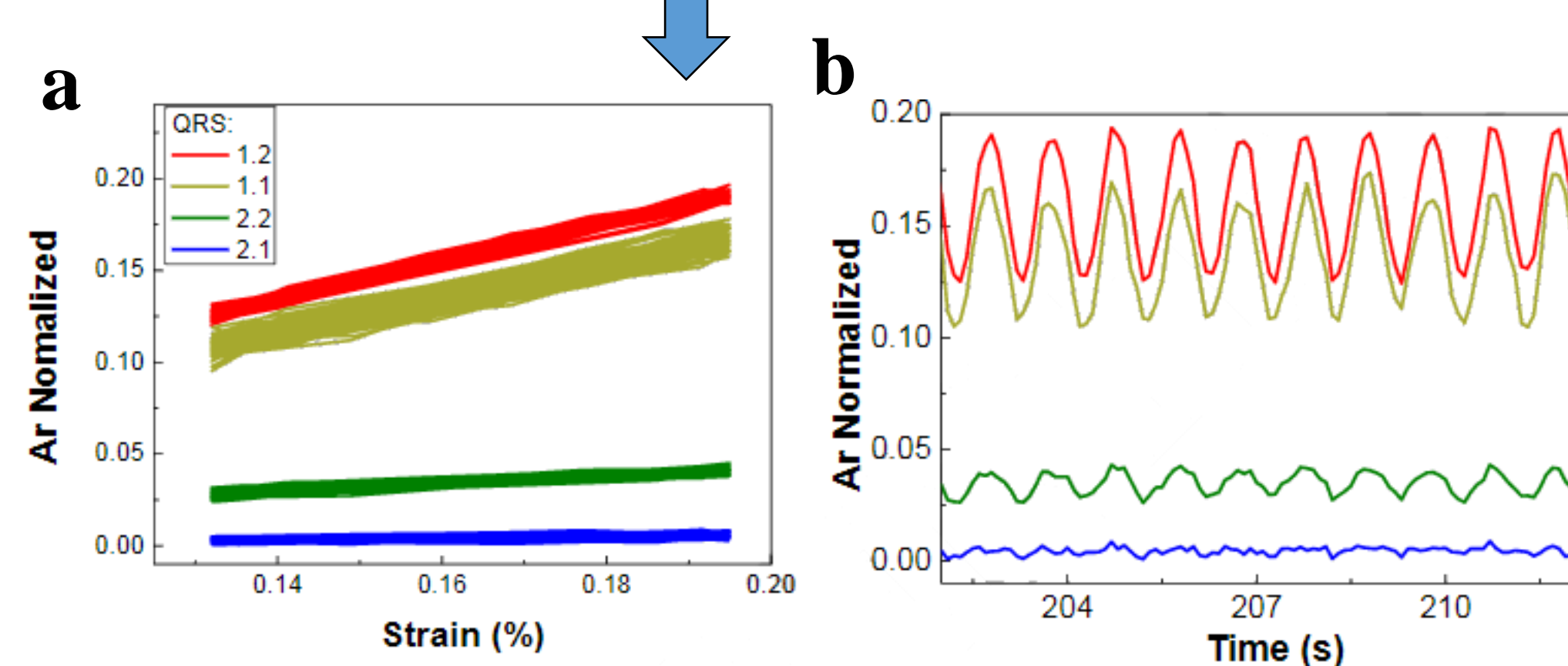


Fig. 5. Electrical behavior of four QRS in CFRP specimen (a) Normalized electrical resistance ( $A_r$ ) of the four QRS as function of strain (b) Representation of their electrical response with time according to the deflection of the beam [6].

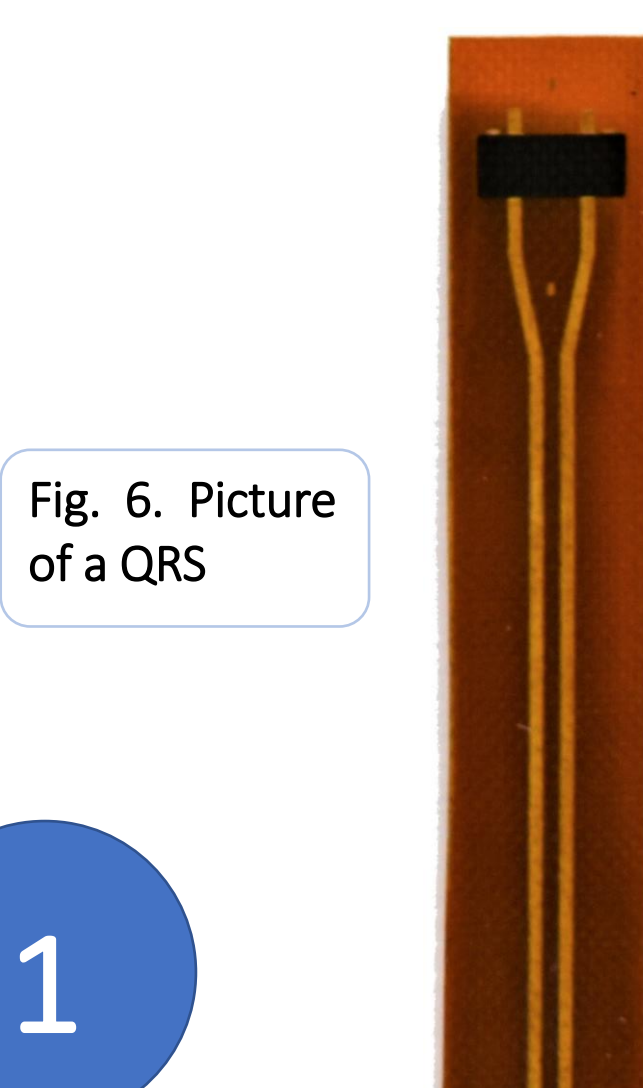


Fig. 6. Picture of a QRS

As presented in Fig.5. the QRS can follow the deformation cycles undergone by the CFRP during the three point bending test. These results were obtained using the acquisition device named QR-KUB (developed by SENSE In). This device supplies the QRS at 1V to question them during a test.

To ensure the compatibility of the QPS with the host composite, the nanocomposites were designed based on epoxy resin. Energy harvesting tests have been carried out to evaluate the performance of the QPS. The devices are positioned on carbon fibers/epoxy composite support. On this support, different events have been simulated by applying a force of 2N over several distances of the QPS. Fig. 7. below shows the evolution of the energy (pJ) recovered as a function of time for various events: during micro-deformations at 1cm and 20cm from the QPS, then during successive friction at 20cm from the QPS. For each event, the equivalent harvested tension is presented.

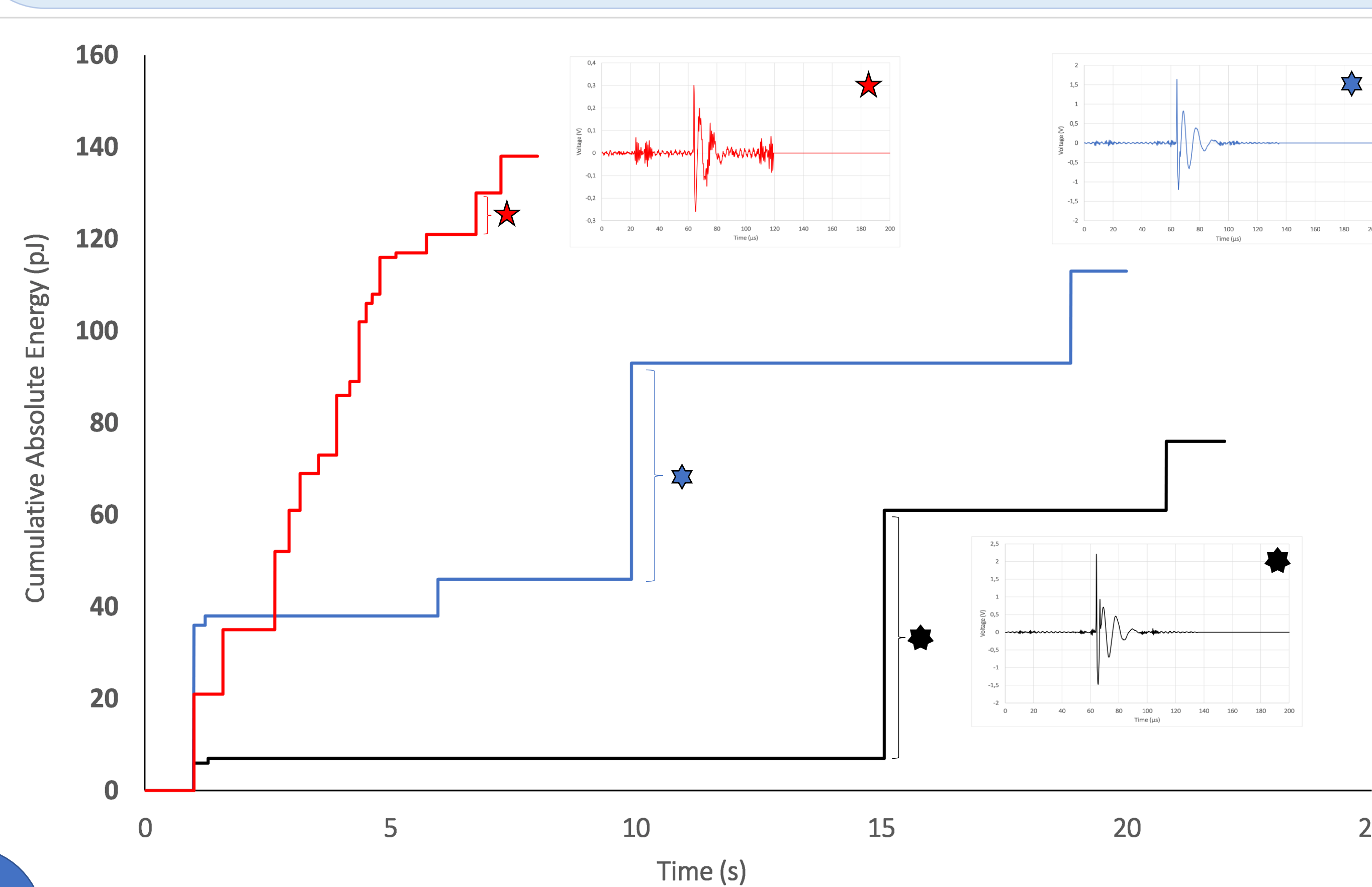


Fig. 7. a) Cumulative absolute energy (pJ) as function of time and the type of event; b) Evolution of the tension recovered as function of time and the type of event. ★ micro-deformation at 1cm from the QPS; ★ micro-deformation at 20cm from the QPS; ★ friction at 20cm from the QPS

The recovered electrical voltage is high enough to power supply the QRS !

## CONCLUSION

- The electric voltage recovered by the QPS would be sufficient to supply a QRS.
- The transfer of this tension from the QPS to the QRS still requires investigations.
- Preservation of the mechanical properties of the host composite with an integrated QPS shall be validated.

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