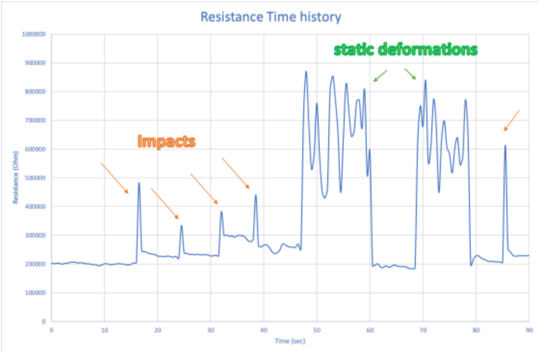


Fig. 9 Time-averaged history of resistance between B and C electrodes under dynamic (impacts) and static loads.

Furthermore, with the same set-up it was acquired the fast response (sampling rate fixed at 5000Hz) from two electrodes of the plate during the free-decaying response after an impact. The time history and the corresponding Fast Fourier Trasformed spectrum are reported in Fig. 10. The electrodes were subjected at a driving voltage of 5 V.

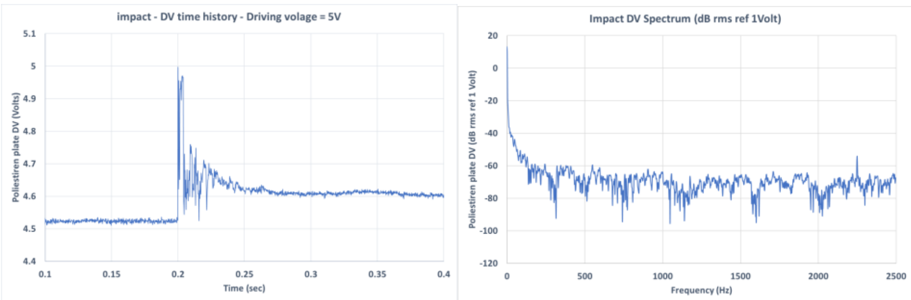


Fig. 10 Fast response of plate (DV) after an impact in time (s.f.=5000Hz) and FFT

From this first attempt of analysing fast dynamic electro-mechanical behaviour of the nano-filled plate it is clear that the response after an impact is fast enough to excite a wide band also in terms of voltage variations (as can be seen also from the spectrum where relevant response values are evident until at least 500Hz). Furthermore, from the time-history of the voltage drop it becomes evident that the voltage itself after a sudden excitation like an impact is composed by a fast behaviour (rapid oscillations in time) and a slower behaviour still conditioning the DV values after the fast oscillation tend to disappear. This characteristics will be better investigated in the third set-up configuration.

3.3 Third configuration – sensor bonding on a cantilever beam

The third and last set-up configuration presented in this work represent a first application of the nano-filled material as structural sensor. In order to test the structural sensing capabilities of the produced material a small rectangle (1.5cm x 3cm) of the material produced as presented in paragraph 2 has been bonded by a structural adhesive on a thin alluminum plate (size 3cm width and 30cm length) constrained as a cantilever beam (See Fig. 11). The sensor has been instrumented with four electrodes on the sides of the rectangle.

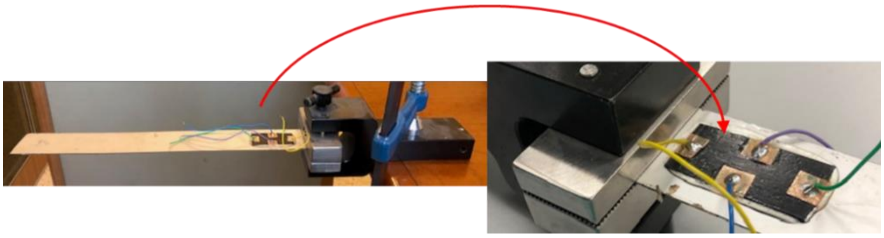
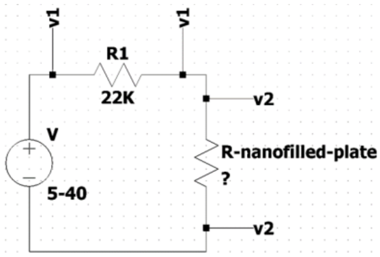


Fig. 10 Cantilever beam sensorised with nano-filled sensor at the root and instrumented with four electrodes on the sides

The experimental set-up was made by the sensorised beam, a multichannel National Instrument acquisition board type NI USB-6466, a stabilised voltage source, a known valued resistance and a small circuit connecting all the components as from the following scheme:



$$R_{nanop} = \frac{V2}{V1} * R1$$

Fig. 11 experimental set-up circuit scheme and sensor resistance equation

Voltages V1 and V2 were acquired by two acquisition channels of the NI board with available sampling rate up to 2 MHz. The voltage source permitted to change the excitation voltage of the sensor between 5 and 40 Volts.
A preliminary study of the electro-mechanical static behaviour was conducted measuring the resistance of the sensor at varying loads (applied at beam's tip) and excitation voltage. The results are presented in Fig. 12.

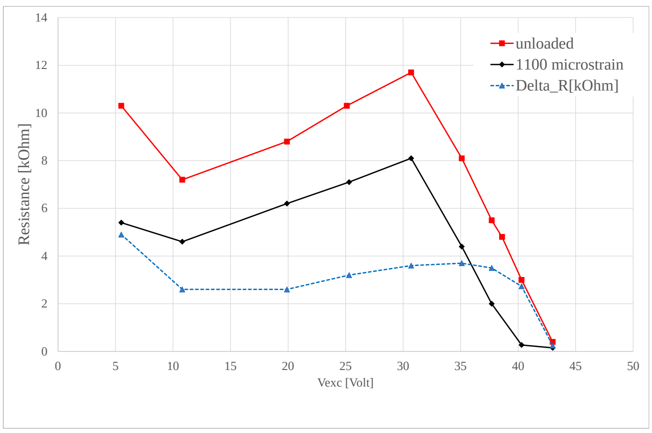


Fig. 12 Electro-mechanical behaviour of nano-filled sensor at varying static loads (at beam tip) and excitation voltage.

Finally, applying a dynamic load at the tip (impulse), the dynamic resistance from the sensor has been acquired with a sampling rate of 2KHz and, from this signal an RMS value each tenth of second has been evaluated in order to analyse both the fast and slow behaviour of the resistance under free response of the beam after an impulsive excitation. In Fig. 13 the two measures are presented.

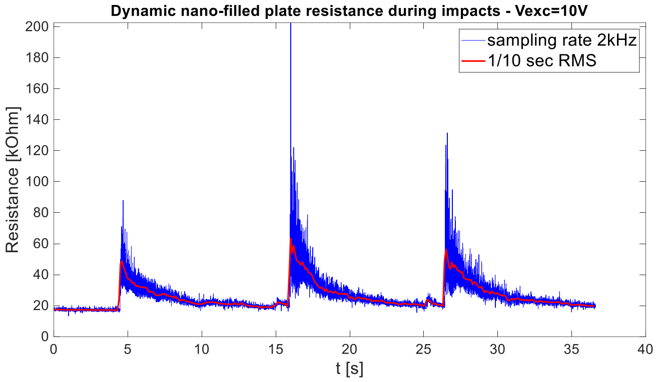


Fig. 13 Dynamic (fast and slow) resistance of the nano-filled sensor after impacts (free-response)

From Fig. 13 is possible to distinguish a fast resistance behaviour following the beam vibrations time-history pattern (blue line) combined with a slower behaviour do to a sort of electrical inertia (capacitive effect) that has always been noted during dynamic acquisitions (red line).A final interesting result has been obtained subtracting the slow behaviour from the full response: the final signal obtained has the classical vibration pattern of a damped dynamic free-response of a beam under impact load as expected. This result open to possible use of nanofilled plates as cheap sensors for dynamic response acquisition for, as an example, modal analysis and/or impact detection.

4 CONCLUSIONS AND FUTURE WORK

This work present the latest activities carried out by the authors in the field of nanofilled piezo-resistive composites. These materials, in the form of thin plates, can be envisaged both as a possible thermoplastic layer in a composite lay-up providing a full sensitive layer as well as can be shaped as small sensors of arbitrary geometry and secondary bonded on a metallic or composite structure. The presented combination of insulating matrix and conductive nano-fillers presented interesting performances in terms of static as well as dynamic electromechanical behaviour under varying configurations of electrodes, excitation voltages and experimental set-ups. Next step will be oriented to a quantitative characterization of some specific shapes of these materials in order to measure the gauge factor of a set of sensors obtained from a nano-filled plate both in static anc dynamic load conditions. In terms of application this composites will be employed for Structural Health Monitoring applications in combination with machine learning algorithms capable to extrapolate essential information about loads, strains and stresses levels in the structures even considering the evident non linear nature of the electro-mechanical behaviour presents.

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