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Variable capacitor energy harvesting based on polymer dielectric and composite electrode

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Micro energy harvesters which transform mechanical to electrical energy today suffer from high production cost in most cases. Therefore this work focuses on a polymer based capacitive harvesters which can be fabricated with help of roll-to-roll low cost methods. In contrast to electrostatic MEMS based parallel plate transducers or dielectric elastomer systems here, the capacitance is varied as function of the mechanical load by changing of the top electrode area with help of an electrically conducting composite elastomer. With this approach the power density can be increased over the other concepts since high-k dielectrics can be used for the capacitor.

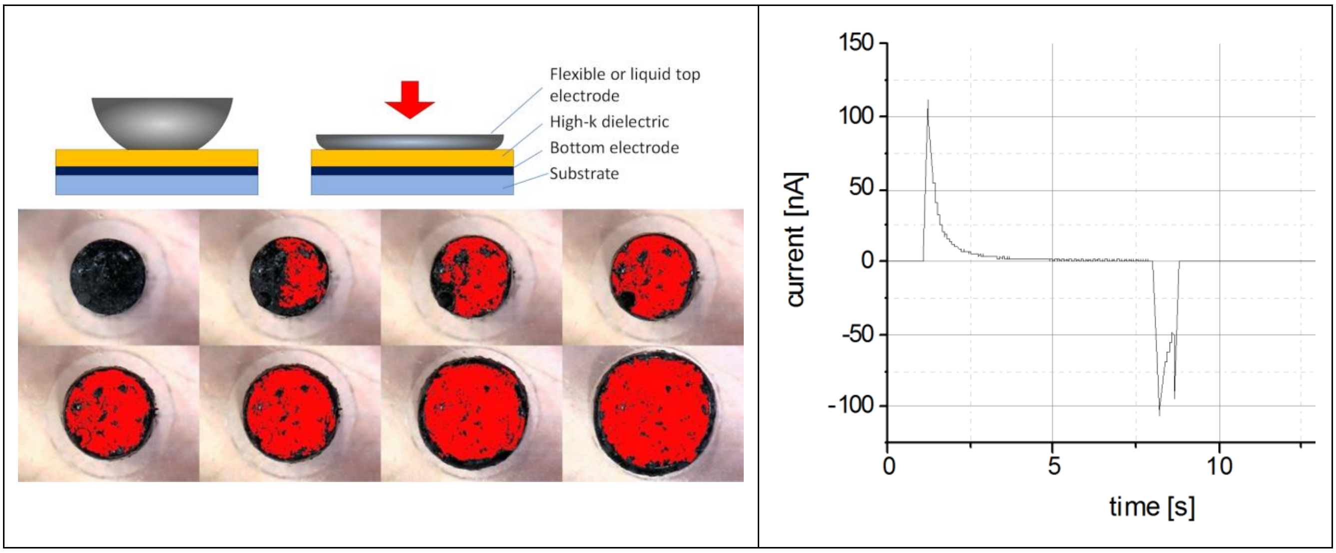
These flexible energy harvesters are especially intended for wearables including smart textiles, shoes and other applications where mechanical compliance is needed.

Numerical simulation was used to identify the influence of material parameters and parasitic circuit elements on the harvester performance as function of actuation frequency. FEM Maxwell simulation of the composite electrode shows, that not only high electrical conductivity of the electrode is important but conducting particles at the electrode surface must be distributed homogenously at a mean distance below 1 µm and should not be covered by the polymer matrix.

An equivalent circuit model was used to investigate the influnce of the leakage currents inside the dielectric (R_p) and the bulk resistivity of the elastomer electrode (R_s). Losses in R_s are not only a function of frequency but also on rise and falling times of the capacitor changes. For typical low frequency operation (0.1 … 10 Hz) R_p should be above 10 GΩ per square centimeter. Too high Rp values can prevent energy harvesting.

First experiments with state of the art polymer thin film dielectrics and electrodes have been performed to prove the harvesting principle with elastomer electrode. The specific capacity is ca. 5 times smaller in comparison to a metal electrodes. Charges between 25 and 70 nAs per cm^2 have been transferred per cycle at 100 V/200 V while the maximum capacity was between 0.4 and 0.8 nF/cm^2. At the target value of 20 nF/cm^2 a power of 0.4 mW could be generated at 0.5 Hz.

Keywords: energy harvesting, capacitive transducer, composite polymer, high-k dielectric, equivalent circuit


Flexible or liquid top electrode
High-k dielectric
Bottom electrode
Substrate
150
100
50
0
-50
-100
current [nA]
0
5
10
time [s]