Organic thermoelectric device based on a stable n-type nanocomposite printed on paper.

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(PEDOT)_xV₂O₅ stability in ambient conditions.

Stability in ambient conditions is an important parameter to consider in a thermoelectric material, as a stable material can ensure longevity of OTEG devices. Figures S1(a) and S2(b) show the evolution of electrical conductivity and Seebeck coefficient (respectively) in function of exposure time in ambient air of $(PEDOT)_{0.03}V_2O_5$ and $(PEDOT)_{0.5}V_2O_5$ samples.

As shown on figures S1(a) and S1(b) electrical conductivity and thermopower show little to no variation over a period of at least 6 months. Thus, nanocomposites (PEDOT)_xV₂O₅ show an overall robust stability in ambient air.



⁽a)



Figure S1. (a) Evolution of electrical conductivity with time of storage at ambient air. (b) Evolution of Seebeck coefficient with time of storage at ambient air.

Temperature dependence of thermoelectric properties of materials, and thermoelectric performance of inks.

As shown in Table S1, formulation of $(PEDOT)_{0.03}V_2O_5$ into printable ink has little influence on its thermoelectric properties. The Seebeck coefficient remains unchanged, while the electrical conductivity experiences a very small reduction from 0.16 S cm⁻¹ to 0.15 S cm⁻¹ (mean value), a difference lower than the margin of error (0.03 S cm⁻¹).

The data in table S1 also shows the thermoelectric properties variations of both PEDOT:PSS and (PEDOT)_{0.03}V₂O₅ at an applied temperature of $\Delta T = 20K$ (T = 318.15 K). Upon application of a $\Delta T = 20K$, (PEDOT)_{0.03}V₂O₅ samples show a slight increase in electrical conductivity from 0.16 S cm⁻¹ to 0.175 S cm⁻¹; this slight increase in σ is explained by the thermal excitation of polarons and their increased mobility in localised states (small polaron hopping). However, at a temperature of 318.15 K of PEDOT:PSS samples, the electrical conductivity has a slight reduction from 600 S cm⁻¹ to 585 S cm⁻¹; indeed PEDOT:PSS shows a semi-metallic behaviour. In both materials, the Seebeck coefficient didn't show any variation at this temperature range.

In either case, the variation of TE properties is extremely low at $\Delta T = 20$ K. Thus, we consider TE properties of both materials nearly independent of temperature at $\Delta T = 20$ K.

Table S1. Thermoelectric properties of ink formulation of (PEDOT) _{0.03} V ₂ O ₅ , and influence of an applied $\Delta T = 20K$ temperature on thermoelectric parameters of
(PEDOT) _{0.03} V ₂ O ₅ , and PEDOT:PSS.films.

Tupo		Ink formulation			
туре	(PEDOT J _{0.03} V ₂ O ₅		(PEDOT J _{0.03} v ₂ O ₅	FEDUI.F35	PEDUI .P33
	At T = 298.15K	of	At ΔT = 318.15K	At T =	At ∆T =
		(PEDOT) _{0.03} V ₂ O ₅		298.15K	318.15K
Electrical	0.16±0.03	0.15±0.03	0.175±0.02	600 ±70	585 ± 57
conductivity					
(S cm ⁻¹)					

Seebeck	-350±17	-350±20	-350±20	17 ±1.5	17 ±1.5
coefficient					
(µV K⁻¹)					
Power Factor $(\mu Wm^{-1}K^{-2})$	2 ± 0.524	1.85 ± 0.59	2.144 ± 0.55	17.12 ± 4.6	16.9 ± 4.6

Bending tests on OTEG device and influence of device bending on power output.

The printed thermoelectric device was attached to two ceramic pieces of different radiuses (1.6 cm and 1 cm). The device was also attached directly to the heat source (Peltier module) unbent (infinite radius of curvature). Figure S2 shows the evolution of power output of the device in function of its radius of curvature. The power output has remained relatively constant with inward bending with a very slight decrease from 0.34 nW (unbent) to 0.332 nW at bending of 1 cm of radius of curvature.



Figure S2. OTEG printed on paper showing a relatively constant power output with inward mechanical bending.

Finally, the devices internal resistance is measured with outward bending (fig. S3). The resistance suffers a slight increase from 515 K Ω at infinite radius of curvature (unbent) to 572 K Ω 1.2 cm radius of curvature (outward bending).



Figure S3. OTEG printed on paper showing a slight variation of internal resistance with outward mechanical bending.

Electrical conductivity and absorption of paper substrate.

Figures S4(a) and S4(b) show the variation of electrical conductivity of thermoelectric materials (PEDOT:PSS and (PEDOT)_{0.03}V₂O₅ respectively) deposited on paper. Naturally the electrical conductivity should be independent of films thickness, however this is not the case for films deposited on paper as the paper substrate partially absorbs the material. At lower thicknesses (below 1 μ m) the electrical conductivity is near zero and it starts to have materials electrical conductivity at thicknesses above 1.5 μ m. Thus, the partially absorbed into paper portion of thermoelectric materials doesn't contribute to devices performance, and can be neglected in the FF consideration. This behaviour can be explained by the fact that porosities of the paper, when the ink is absorbed in the substrate, hinder the percolation between domains of absorbed ink. This is evident for thicknesses below 2 μ m, where the quantity of material and the subsequent thickness is too small to ensure percolation. We thus consider that the wettability of the ink is not perfect on paper (see measured contact angles in fig. 8 (a) and 8(b) in main article).



Figure S4. Low electrical conductivity of PEDOT:PSS (a) and $(PEDOT)_{0.03}V_2O_5(b)$ at lower thicknesses (below 1 μ m) on paper shows that the partially absorbed materials in paper have no contribution on devices performance.