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PEDOT:PSS/PEO: a melt-processable blend for flexible conductive electrodes?

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INTRODUCTION

Large R&D efforts are currently observed in smart polymer materials with advanced functionalities coupled to additive processing/prototyping concepts such as fused deposition modeling (FDM). In these fields, melt-processable flexible electrodes with high electronic conductivity represents one of the key challenge to address¹. Polymer filled with carbon or metallic nano/micro-objects is currently the unique solution for FDM. However, this route is clearly restricted: low conductivity, high rigidity, narrow processing conditions, extrusion die degradation, etc²...

In this context, the substitution of (nano)fillers by intrinsic conductive polymers such as poly(3,4-ethylene dioxythiophene) : polystyrene sulfonate (PEDOT:PSS) can be of high interests to develop highly-conductive flexible electrodes by FDM (or other prototyping processes)^{3,4}. The objective of this work is to investigate the use of PEDOT:PSS/poly(ethylene oxide) (PEO) blends to develop a melt-processable material for flexible electrodes. Here, we study the impact of PEO content on the electronic conductivity of PEDOT:PSS/PEO blends at various processing stages.

EXPERIMENTAL STUDY

The blends were prepared from aqueous solutions of PEDOT:PSS (Clevios PH1000 HERAEUS), ethylene glycol and PEO (Mv = 200,000, Sigma Aldrich). Solutions were homogenized by stirring and sonication and thin films were then prepared either by (i) drop-casting (DC) (on a hot plate, 70°C for 45 min and 120°C for 1h) or (ii) extrusion/thermocompression (ExTC) (120°C, water evaporation at 70°C before melt processing). Films were post-treated by water or sulfuric acid (96 %) for 5 min at room temperature. Films were gently rinsed 3 times with water and dried in an oven (70°C for 4 h and baked on a hot plate at 120°C for 5 min). The electrical properties of the films were measured by the Van Der Pauw 4-probes technique. Morphologies were revealed by Scanning Electron Microscopy equipped with an Energy Dispersive X-Ray spectrometer (EDX).

RESULTS AND DISCUSSION

The Table 1 shows the impact of PEO and ExTC on the electronic conductivity of as-prepared PEDOT:PSS/PEO blends. A drastic drop of the electronic conductivity is observed after ExTC processing independently of the PEDOT:PSS concentration. The conductivity of the PEDOT:PSS with 60%wt PEO is divided by a factor 2000 after ExTC. These trends can be partly attributed to the

loss of the homogeneous distribution of the PEDOT:PSS in PEO as depicted in Fig. 1.

However, the conductivity of the PEDOT:PSS/PEO blends produced by ExTC can be significantly enhanced by post-treating with sulfuric acid to reach interesting conductivities close to 4 S/cm. This treatment tends to increase the predominance and the organization of the conductive phase.

Processing	90 % wt PEO	60 %wt PEO
Drop-casting (DC)	0,23±0,03	245±72
DC/thermocompression (TC)	0,22±0,04	107±17
ExTC	$(4,5±0,4).10^{-5}$	0,12±0,02
ExTC + water post-treatment	$(6,0±0,7).10^{-4}$	0,18±0,02
ExTC + acidic post-treatment	0,32±0,03	4±2

Table 1 Impact of the PEO content and processing on the conductivity of PEDOT:PSS/PEO blends (conductivity given in S/cm).

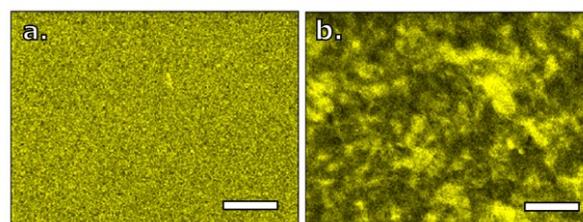


Fig. 1 Distribution of sulfur by EDX in PEDOT:PSS/PEO processed by DC (a) and ExTC (b) (Scale bar: 25 μ m).

CONCLUSION

Within this study, PEDOT:PSS/PEO blends were processed by extrusion technologies into thin film and high electronic conductivity could be maintained using an adequate post-treatment. With conductivity similar to some commercial polymer/carbon composites², PEDOT:PSS/PEO blends represents a promising alternative to produce flexible electrodes using conventional and advanced processing technologies of the plastic industry.

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