# TEXTILE SENSORS & ACTUATORS BASED ON CONDUCTIVE COMPOSITES

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## Introduction

Industries using advanced technologies - telecommunications, media, etc. - need innovative materials which can be integrated into intelligent and communicative textile structures. These materials in turn, require electronics and sensors which allow the transformation of physical phenomena, such as a strain deformation, into a measurable electrical signal.

A new generation of smart sensors has been designed for such flexible materials, because conventional sensors and gauges were not suitable as their general mechanical characteristics were incompatible with those of textile structures. Optical fibres [1,2], piezoelectric polymer fibres [3], conductive polymers used in coating or spinning [4-7], and Conductive Polymer Composites (CPC) [8] are some of the developments which seem to respond to these specifications.

The aim of this work is to develop smart flexible sensors adapted to textile structures, able to measure their strain deformations. It is also possible to use similar sensors to measure the fabric temperature & moisture. The sensors are "smart" because of their capacity to adapt to the specific mechanical properties of textile structures that are lightweight, highly flexible, stretchable, elastic, etc. The material used for the sensor is based on a thermoplastic elastomer (Evoprene)/carbon black nanoparticle composite, and presents general mechanical properties strongly compatible with the textile substrate. The preparation procedure is fully described, namely the optimization of the process in terms of filler concentration in which the percolation theory aspects have to be considered. The sensor is then integrated on a thin, lightweight Nylon fabric, and the electromechanical characterization is performed to demonstrate the adaptability and the correct functioning of the sensor as a strain gauge on the fabric. A normalized relative resistance is defined in order to characterize the electrical response of the sensor. Finally, the influence of the strain rate (sensor bandwidth) and environmental factors, such as temperature and atmospheric humidity, on the sensor performance is investigated.

## Materials

The polymer matrix used is Evoprene 007 (EVO), from Alpha Gary, a Styrene-Butadiene-Styrene (SBS) co-polymer. It belongs to the class of thermoplastic elastomers and presents outstanding mechanical properties (weak Young modulus and high elasticity). It has a density of 1.16 $g.cm^{-3}$, and a melting-point of 82°C. Acrylic latex is used to make a protective film layer on the sensor when it is integrated in the fabric. This latex, Appretan® 96100 from Clariant, is an aqueous acrylic polymer solution which gives rise to a soft transparent film upon drying. The tensile behavior of the film has been investigated and found to be adapted to the textile fabric used. The conductive filler particles, Printex L6 supplied by Degussa Corp., are in the form of a highly structured carbon black powder. The CB particles were systematically dried for 12 hours at 80°C prior to use in the CPC preparation.

## Experimental

The novel method developed in our laboratory uses a solvent mixing medium at low temperature. It was developed as an alternative to the melt mixing process traditionally used to make CPC. Among the different solvents which have been tested, chloroform has given the best results with the EVO/CB mixture. Both the polymer and CB were introduced, in adapted quantities, into a closed vessel with the chloroform (Aldrich). The preparation parameters were as follows: the temperature was set at 55°C, and the time of mixing was 5 hours. The mixtures were then left to dry at room temperature until all the chloroform had evaporated (max. 24 hours): the final result was a homogeneous solid block of composite, which was then cut out in pellets. Several samples with different filler concentrations were prepared and their resistivity has been measured and shown in Fig. 1.

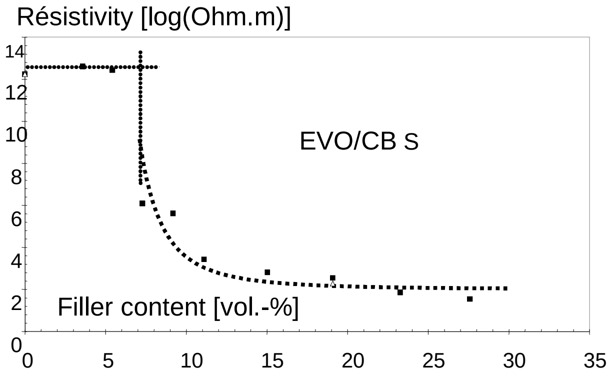


Fig. 1. Resistivity vs. CB nanoparticles concentration – percolation threshold

The CPC sensor is integrated on a Nylon fabric with the help of a mask and electromechanical measurements are performed to test the adaptability of the system as a strain gauge on a fine and flexible structure. A small amount of the CPC solution (Evoprene/carbon black/chloroform) prepared by the solvent process method is deposited at one end of the mask, and scraped over the length of the mask to the other end with a blade. The mask is then removed, and after a time of drying at room temperature for 2 to 3 hours maximum, the evaporation of the chloroform solvent leaves a fine black track of Evoprene/carbon black conductive composite. The thickness of the track is measured with an optical profilometer (Altisurf 500, Coltec) and is found to be equal to 16 µm (Fig. 2).

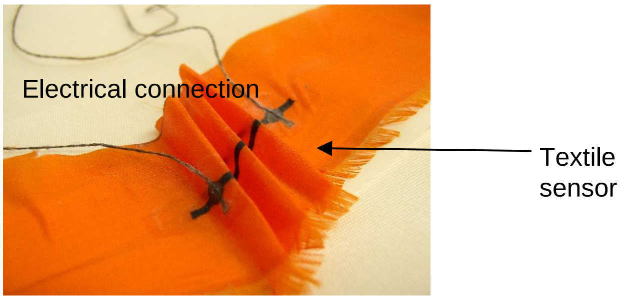


Fig. 2. CPC textile sensor

The dependence of the sensor electrical properties on climatic conditions is investigated with a climatic chamber (Excal 2221-HA, Climats®). Fabric test samples are prepared in the same way as in the previous electromechanical measurement. The CPC sensor behaviour has been investigated at different strain rates in order to determine its capacity to measure high speed deformations. The CPC flexible sensors have also been compared to classical metallic strain gauges in order to determine their advantages.

## Conclusion

The design of a flexible strain sensor based on a conductive polymer composite has been realised in this work. The optimization of the sensor in terms of dimensions, geometry, preparation process, and filler concentration has led to a sensitive, reliable strain gauge which can be easily deposited on any flexible substrate such as a textile fabric.

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