
Mechanochromic sensor for measuring high strain in the healthcare sector

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Abstract

In health area, measuring high strain for textile medical device wearing by a subject presents high interest. That's why development of small, flexible sensors capable of measuring high strain has gained considerable momentum in recent years. Currently, no sensor technology on the market can meet these needs. The methods used by industries and researchers are optical, requiring expensive equipment, difficult to transport, and technical to set up. The objective of this project was to develop a small, flexible sensor capable of measuring high strain, and compatible with the healthcare sector. This sensor was also design to be stitched directly on textile orthosis such as lumbar belts and used for moving studies. Our goal is to measure 20-30% strain. The sensor developed is a bound sensor based on mechanochromic.

Mechanochromy is characterized by an optical and physical-chemical phenomenon that causes a material to change color when subjected to mechanical strain. This phenomenon cannot be observed naturally and does not apply to all materials. It is present in amorphous materials, particularly polymers. To observe this phenomenon, adding a colored additive is essential. This colorant must have some criteria: it must be compatible with the polymer matrix and have photoluminescent optical properties. The most commonly used additives are those from the chromophore family.

In this study, two polymers with the same additive were studied: ethylene-octene (OE) copolymer, better known as POE and polypropylene (PP), and a food colorant as additive, bis(benzoxazolyl)stilbene (BBS). BBS has numerous aromatic rings that interact with each other and the material to form aggregates, also known as excimers. The latter dissociates to form a new metastable molecule called a monomer. Excimers and monomers do not have the same potential energy level. Under UV light excitation, this difference is reflected in the emission of a specific wavelength for excimer (495nm: green) and monomer (430nm: blue). The formation and dissociation of excimers are responsible for the appearance of the mechanochromic phenomenon. To obtain measurement of different strain, we decided to mix both polymers in our sensor. Five blends were created: 80%PP-20%POE; 60%PP-40%POE; 50%PP-50%POE; 40%PP-60%POE, and 20%PP-80%POE.

To test the mechanical properties and the mechanochromy phenoma link to the strain, different sensors were created. Specimens were cuted in 500 μ m-thick plates made of the granules

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using a heated press. The parameters used were: pressure 1.25 bar, temperature 200°C for two minutes, followed by rapid cooling. BBS additive were included in four different concentrations (0.2%, 0.5%, 0.7%, and 1% BBS by mass) during the pellet manufacturing process. Next, samples were cutted from these plates with a die in the shape of a standardized type 5A tensile test specimen per ISO527-2: 2012. Five tensile tests were performed by polymer types and BBS concentration. These tests were coupled with an optical test rig specifically developed at ICA laboratory for mechanochromy characterization. The optical bench consists of six LEDs and optical fibers that transmit light spectrum to a spectrometer during the test. The spectra are recorded in real-time using a trigger and in-house Python code. The aim was to deform the sensor by up to 50% at a strain rate of 5mm/min and record the light spectrum during the test.

The recorded spectra revealed three peaks at wavelengths characteristic of BBS: 430 nm, 460 nm, and 495 nm. The first is associated with the presence of monomers (blue). The second is linked to the chemical composition of BBS. The last gives information on the presence of excimers (green). Analysis of the spectra focuses solely on the evolution of the intensity ratio between excimer and monomer.

Results show mechanochromy phenomena in all types of polymer when BBS concentration is higher than 0.7%. The sensor changes color from green to blue in UV excitation. The optimum dosage to be used to detect the phenomenon is 1% BBS with an associated strain rate of 20%. Only POE was not suited to our need to measure strain rates in the 20-30% range. Mix polymer is needed to answer our needs. The 60%PP-40%POE mixture is the better compromise between mechanical properties and mechanochromy phenomena. We have therefore obtained convincing results from the use of mechanochromics to measure high strains.

In conclusion, these initial tests are encouraging, as they enable us to imagine the possibility of creating polymer mixtures capable of measuring specific bound values with accuracy. The sensor's properties make it be able to measuring high strain on all types of textile. This sensor could also be easily positioned on medical textiles for movement studies or textile orthosis tightening tests. We can also imagine sensors with several bounds. The use of elastomers could also make it possible to create reversible sensors. This work opens the door to new ideas.