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PIEZOELECTRIC FILAMENTS PRODUCED BY COEXTRUSION

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Abstract - Considering the significant interest of both the academic and industrial communities in the fields of i/e-textiles (interactive/electronic textiles), the number of developed applications is far below the expected. This fact is mainly related to the difficulties on the development of production methodologies adequate to industrial scale processes. In this areas the integration of piezoelectric materials, that possess sensing/actuating capabilities, such as poly(vinylidene fluoride), PVDF, and can be processed using conventional processing techniques, is very promising and has encouraged a large number of research works. However, until now, most of the developed production methodologies are difficult to adapt to the industrial scale. This work reports recent developments achieved, in the framework of a research project, on the production of piezoelectric filament by coextrusion of PVDF and electrical conductive layers. The developed production methodology involves a conventional coextrusion line, for which a coextrusion die was designed to produce a multilayer filament. This filament comprises an inner layer of an electrically conductive Polypropylene grade and a middle layer of PVDF and is coated with an electrical conductive ink. The piezoelectric response of the produced filaments will be also presented.

Keywords: i/e-textiles ; electroactive filaments; coextrusion.

Introduction

Poly(vinylidene fluoride) (PVDF) motivated the interest of both industrial and academic communities due to its exceptional pyro- and piezoelectric properties [1-3]. The PVDF properties depend both on its degree of crystallinity and orientation of its crystalline phase, which are strongly dependent on the processing conditions employed during production [1,3-6].

A polymeric piezoelectric device comprises at least one piezoelectric layer and two electrically conductive layers, one at each side of the central layer, which are used as electrodes for the connection of electronic conditioning/drive equipment.

The most common form of piezoelectric PVDF based devices are the flat film. Its production starts from the extrusion of a PVDF layer that is subsequently stretched, poled and, finally, coated by metallization. Just a few research works available in the literature focus on the development of filament shaped PVDF sensors. Walter et al. [7] have studied extensively the phase transitions of extruded PVDF monofilaments that were used in the production of composite parts, which exhibited piezoelectric activity. Lund et al. [8] report the production of two-layered filaments, showing that the electroactive phase content is not affected by the conductive inner core and that the β-phase content depends only on the processing temperature and stretch ratio, as happens for the single PVDF filaments. In the works of Mazurek et al [9], that propose a sequential processing methods for the production of piezoelectric cables, it was shown that the cooling at -30ºC of PDVF, after stretching, increase the β-phase content, while the coating required for the placement of the outer electrode promotes a significant reduction.

In this work, the development of a new filament shaped PVDF based sensor is proposed, with a coaxial arrangement of the electrode (electrical conductive) and PVDF layers, that is produced by coextrutison. This device is suited for a new range of application, particularly the ones that involve innovative e-textile applications.

Piezoelectric Filament Production

The production line for the piezoelectric filament starts with the coextrusion of the filament inner (electrode) and middle (PVDF) layers, see Fig. 1. For the inner and middle filament layers were used, respectively, an electrically conductive polypropylene (Premix 1396) and an extrusion grade PVDF (Solef Ta-1010).

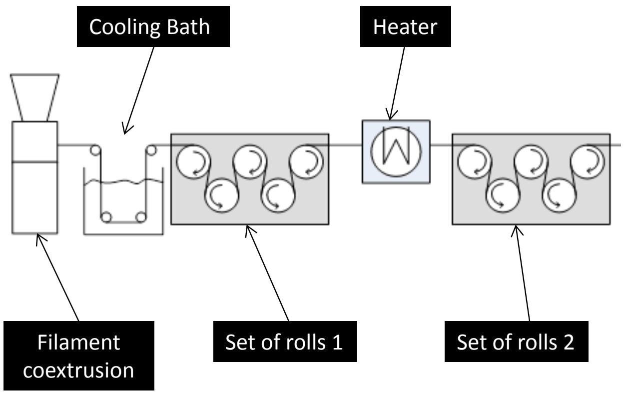

Figure 1 - Extrusion line used to produce the two layered coextruded filaments.

The velocity imposed on the *Set of rolls 1* (Fig. 1), allow to control the linear velocity of the filament at the die exit and, consequently, its diameter. After leaving the die flow channel, the filament is cooled in a water bath to room temperature and is then heated in Heater (Fig. 1), which is a forced convection air temperature controlled oven. Inside the Heater, when it reaches a temperature at which is deformable, the filament is stretched, due to the pulling force promoted by the *Set of rolls 2* (Fig. 1), that should be set to a linear velocity higher than the one at *Set of rolls 1*. The draw ratio imposed to the filament is determined by the relation between the linear velocities V_2 and V_1, respectively, the linear velocity of *Set of rolls 2* and *1*, and is given by $R=V_2/V_1$. The cooling and heating steps are required to assure a better control of the temperature at which the filament draw takes place. At the end of the extrusion line the continuous produced filament is wound.

Afterwards the filament is coated with a silver conducting ink, which forms its third (outer) layer. The two conductive layers are then connected directly to a voltage source and subjected to high voltage, to obtain a poled PVDF layer.

Piezoelectric Filament Characterization

Upon production the piezoelectric filament was tested using two different set-ups, being the generated electrical signals measured with adequate equipment. The two tests performed were: (i) compressing manual and transversely the filament; (ii) submit the filament to tensile loading-unloading cycles in a universal testing machine, with an amplitude of 0.2 mm at a speed of 100 mm/min.

The results obtained for the manual compressional and tensile tests are illustrated Fig. 2 and 3, respectively. In both tests the piezoelectric behavior of the produced filaments is evident.

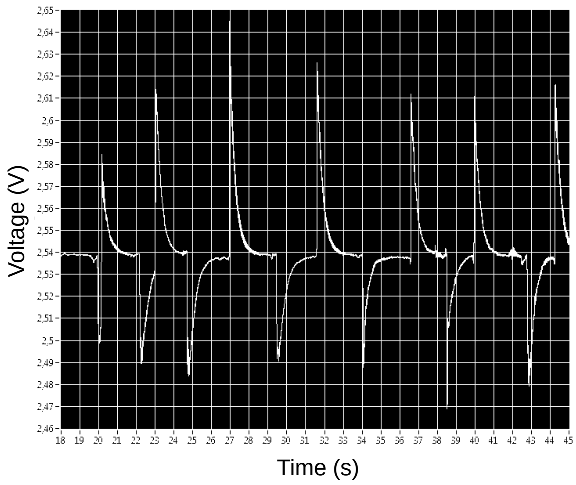

Figure 2. Electrical signal produced in the manual compression test

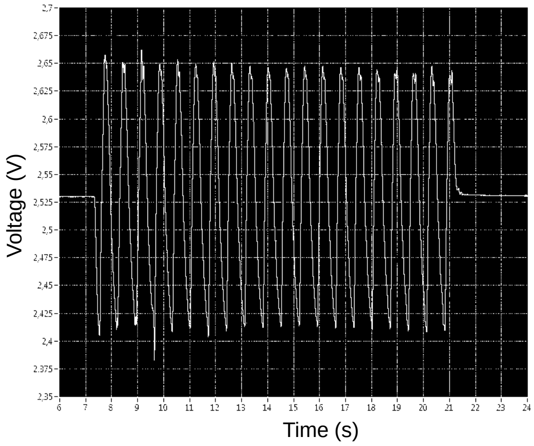

Figure 3. Electrical signal produced in the tensile

Conclusion

The filaments produced in this work, using a coextrusion based process, were shown to generate an electrical signal when stimulated by mechanical stimuli, behaving in a similar way to standard piezoelectric film sensors.

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