ENHANCED ELECTROACTIVE PHASES OF POLYVINYLIDENE FLUORIDE NANOFIBERS FOR BONE TISSUE ENGINEERING APPLICATIONS

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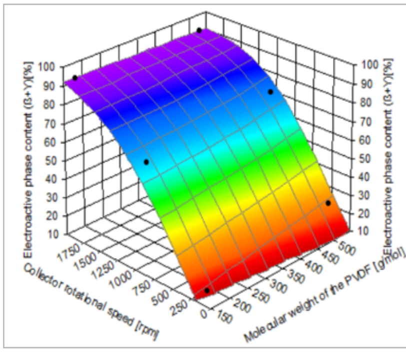
ABSTRACT

Nanofibrous materials produced by electrospinning processes have attracted considerable interest in tissue regeneration, including bone reconstruction. A range of novel materials and processing tools have been developed to mimic the native bone extracellular matrix for potential applications as tissue engineering scaffolds and ultimately to restore degenerated functions of the bone. Currently, there is high interest in designing a material resembling bone tissue, and many scientists are trying to design materials applicable to bone tissue engineering (BTE) with piezoelectricity similar to bone. One of the prospective candidates is highly piezoelectric polyvinylidene fluoride (PVDF), which was used for fibrous scaffold formation by the electrospinning technique [1,2]. In this study, the effect of PVDF molecular weight, fiber spatial arrangements, and electrospinning parameters on polymorph content was investigated. A multi-technique procedure combining spectroscopy and microscopy was used to investigate the phase content in PVDF. The author's idea is to fabricate fibrous scaffolds to enhance cell adhesion, migration, and proliferation.

Two grades of PVDF with low and high molecular weight were investigated along with various electrospinning parameters, such as the rotational speed of the collector, applied voltage, and solution flow rate. A multi-technique approach of microscopy and spectroscopy allows for determining the effect of molecular weight and processing parameters on the content of the electroactive phases.

It is evident from the data in Fig. 1 that the effect of the collector's rotational speed on the content of electroactive phases is strong. In the electrospinning technique, the speed of the collector can be controlled, and it affects the content of the electroactive phases [3]. Such a strong increase in the content of electroactive phases with collector rotational speeds is related to an increase in stretching forces leading to better molecular alignment and orientation in the nanofibers. The influence of molecular weight on the content of electroactive phases is evident only at the lowest rotational speed.



Sample – collector rotational speed [rpm]	F(α) (%)	F(β) + F(γ) (%)	F(β) (%)	F(γ) (%)
1 – 200	88±0.2	12 ±1.2	9 ±3	3 ±4
2 – 1000	35±1.4	65 ±0.7	52 ±6.1	13 ±3.3
3 – 2000	8±2.2	92 ±4	47 ±2	45 ±4.8
4 – 200	76±3	24 ±0.4	15 ±0.6	9 ±4.2
5 - 1000	28±1.9	72 ±2.9	57 ±0.9	15 ±1.3
6 - 2000	11±3.3	91 ±6.3	60 ±2	29 ±1.2

FIGURE 1 The relation between collector rotational speed, polymer molecular weight, and electroactive phases content (left); Electroactive phases content in PVDF nanofibers (right).

Cell viability ADSC cells cultured on PVDF scaffolds with the highest amount of electroactive phases and different rotational speeds of the collector (200, 1000, and 2000rpm), applied voltage 22 kV and flow rate 0.8 ml/h in the presence of ultrasound for 3, 14, and 21 days post-seeding were investigated (Figure 2). The in-vitro analysis shows the non-toxic properties of all specimens. There was slightly lower viability in samples compared to the control. Moreover, all scaffolds reached ≥ 70% values of viability, which is in accordance with the ISO 10993-5 standard connected to the living cells and non-toxic materials. The introduction of piezoelectric scaffolds with the presence of ultrasound has been previously reported and has a positive impact on cell behavior [4]. Ultrasound stimulation can emphatically enhance the properties of the nanofibrous scaffolds due to their bioactivity and biocompatibility [5].

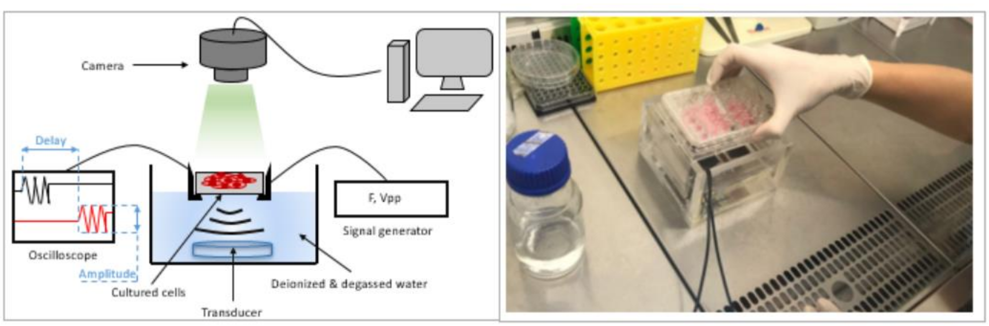


FIGURE 2 Ultrasound Stimulation as a non-invasive mechanical stimulation of cultured cells.

It can be concluded that the higher molecular weight of the PVDF increases nanofibers' dimensions and electroactive phase content. Various electrospinning technique parameters show changes in electroactive phases with the maximum applied voltage of 22 kV and flow rate of 0.8 ml/h. Moreover, the presence of ultrasound during cell culture of human adipose-derived stromal cells proved positive impact on cell behavior. This study can serve as a good reference for the effect of molecular weight and processing parameters on the morphology and properties of electrospun PVDF fibers.

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