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Real-Time Monitoring in Neural Tissue Regeneration: Fist Observations from the PIEZOMAT Project

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smart materials; piezoelectricity; neural tissue engineering; electrospinning

Modern scaffolds designed for neural tissue engineering usually fulfill only one of two essential functions: either they provide a structural matrix that encourages axonal outgrowth, or they act as passive platforms for external measurement techniques. Currently, no material unites these capabilities within a single, biocompatible system. PiezoMat aims to address this gap by engineering a multilayer, nanoparticle-enhanced piezoelectric scaffold that accelerates functional nerve repair while converting mechanical cues arising from cellular activity into a measurable electrical signal [1,2].

The project's primary goal is to develop a bio-inspired scaffold that can track key biological events that accompany the regeneration of injured peripheral or central nerves in real time and without the need for invasive electrodes or fluorescent labels. In short, PiezoMat promises to shift the paradigm from passive, one-off implants to active, self-reporting scaffolds - an advance that aligns with the broader trend towards personalized, feedback-controlled regenerative therapies, and which addresses a clearly articulated need in the field of neural tissue engineering [3].

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 [4]. Such a strong increase in the content of electroactive phases with collector rotational speeds is related to an increase in stretching forces, leading to effective molecular orientation in the nanofibers. The influence of molecular weight on the content of electroactive phases is evident only at the lowest rotational speed. Importantly, the identified electroactive phases are expected to play a crucial role in enabling real-time monitoring of regeneration processes, as their piezoelectric response directly reflects dynamic cellular activity within the scaffold. This capability will be further explored in subsequent stages of the project, where the material will be integrated with nanoparticles to continuously track cell behavior. Such an approach will allow for correlating scaffold properties with biological performance over time, ultimately contributing to the development of adaptive, feedback-driven regenerative therapies.

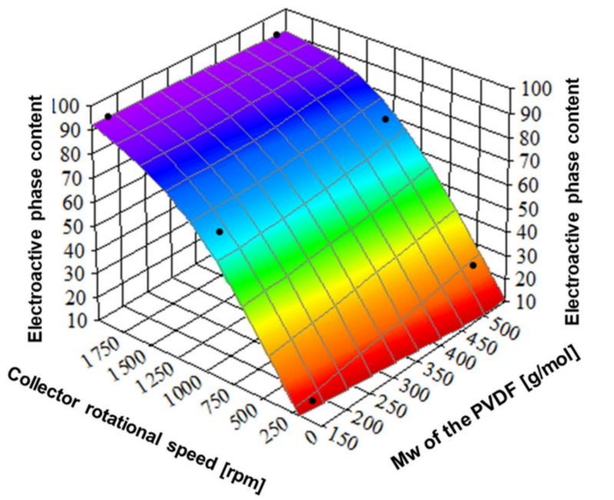

Figure 1. The relation between collector rotational speed, polymer molecular weight, and the electroactive phases content (α+γ).

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