Piezoelectric Substrates Promote Neurite Growth in Rat Spinal Cord Neurons

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Abstract—We tested the possibility that exogenous electrical activity from a piezoelectric substrate could influence neuronal structure in cultured spinal cord neurons. Oscillating electrical fields were delivered to rat neurons via substrates consisting of polyvinylidene fluoride (PVDF) and non-piezoelectric (PZ) films. To induce oscillating electrical fields at the film surfaces, a 50 Hz mechanical vibration was applied. After 4 days of mechanical stimulation, neuronal densities were increased by 115% and neurons grew 79% more neurites, with more than double the branch points, compared with neurons grown on non-stimulated PZ films (p < 0.001). The effects were due to electrical field, because vibration applied to non-PZ films did not increase neurite growth. We conclude that the oscillating electric field produced on PZ polymer substrates can induce plastic changes in neurons of the central nervous system and herein we show its influence on neurite growth and branching.

Keywords—Electrical field, Piezoelectric, Polymer, Neuron, Neuroplastic, Growth factors, Poly(vinylidene fluoride), PVDF.

INTRODUCTION

Stabilizing and remodeling of the dendritic tree is a potential approach for repair of the injured spinal cord. Reduced dendritic arborization accompanies spinal cord injury and many developmental disorders, including autism, Down syndrome, Rett syndrome, psychiatric illnesses, such as schizophrenia and neurodegenerative diseases resembling Alzheimer’s. Promising interventions for these conditions are based on observations that neurite growth can be manipulated by environmental cues in their substrates, including chemical stimulants such as dopamine and BDNF, and specific ranges of physical features, including substrate stiffness, topography, as well as direct electrical stimulation.

This report focuses on the effect of oscillating electrical fields on neurite growth. It is well known that electrical activity, either applied directly by neurons or exogenously from electrodes, can directly influence neuronal structure. In particular, neurite arborization in the developing CNS depends directly on electrical cues from pre-synaptic neurons (for review see Butz et al.). For example, dendrite growth and branching in central neurons is stimulated by activation of voltage-gated sodium and calcium channels stimulates, as well as by synaptic activity.