PDMS/Graphene Composite Electrostimulation Electrodes for Parkinson's Disease Smart Garment

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INTRODUCTION

Parkinson's Disease (PD) is a chronic neurodegenerative disorder that results in various symptoms affecting people's motor function, including bradykinesia, rigidity, gait and balance decline, tremor, and dyskinesia/dystonia [1]. It results in cognitive and motor impairments that greatly impact an individual' autonomy and independence. There is no cure for PD. Interventions for functional improvements require precise management of the movement impairments and their fluctuations across the course of the disease.

Medication is currently the primary treatment modality [2]; however, drug-induced motor complications (dyskinesia, On/Off fluctuation, and dystonia) can be particularly bothersome [3]. Alternatively, orthotics have been developed for mechanical tremor suppression [4]; however, they are generally bulky and heavy. Electrical stimulation has also shown promising results [5], but current products are non-wearable or are limited to a small body area.

Recent advances offer opportunities for functional integration of sensors and actuators to develop comfortable garment-embedded wearable technology that provides big data for precise mobility function monitoring and augmentation. The communication reports of the development of a dry electrostimulation electrode for the garment (Figure 1).

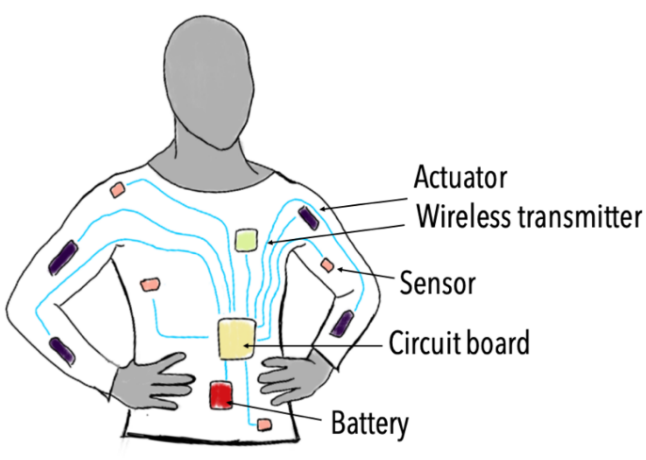

Fig 1 Smart garment for mobility function monitoring and enhancement

MATERIALS AND METHODS

Electrodes were prepared using SYLGARD™ 184 polydimethylsiloxane (PDMS) elastomer (Midland, MI) and a 4wt% water-based graphene dispersion (ACS Material, Pasadena, CA). A silver-plated conductive knitted fabric (Adafruit, New York, NY) was used as a substrate. Different PDMS/graphene ratios, crosslinker concentrations, and curing conditions were explored. The electrodes were characterized in terms of impedance, chemical composition (via Fourier transform infrared spectroscopy (FTIR)), morphology (via scanning electron microscopy (SEM)), and mechanical properties.

RESULTS AND DISCUSSION

The combination of the PDMS and water-based graphene dispersion resulted in porous composite structure. Such a porous structure allows the electrode to be compressed and therefore, can increase the surface area of contact between the skin and the electrode. Samples cured under vacuum resulted in a more adhesion with the conductive fabric compared to samples cured in a regular oven as evidence by SEM. Regardless of the oven used for curing, higher temperatures resulted in decreased mechanical properties. Optimal graphene loading ranged between 5-7%. Graphene concentrations lower than 1.8% resulted in an electrode that was not conductive. Composites with a high graphene loading resulted in a large variability in the electrical conductivity of the electrode and the presence of graphene residues at the surface of the mold, indicating an uneven distribution.

CONCLUSIONS

Washable electrodes have been developed using a biocompatible elastomer and a water-based graphene dispersion. These electrodes offer a solution to bridge the electrode-skin interface effectively. They will be embedded into the smart garment to deliver electrical stimulation to the muscles and help mitigate PD mobility symptoms.

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