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# Artificial muscles for wearable assistance and rehabilitation



**Key words:** Artificial muscle; Smart material; Dielectric elastomers (DE); Polyvinyl chloride (PVC) gel; Actuator; Wearable assistance; Rehabilitation

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# Motivations

1. Traditional exoskeletons have some disadvantages, such as being heavy, bulky, stiff, noisy, and having a fixed center of rotation, which are not good enough for wearable assistance and rehabilitation.

2. Artificial muscles based on soft, smart materials possess the attributes of being lightweight, compact, highly flexible, and have mute actuation, for which they are considered to be the most similar to natural muscles.

# Main ideas

We focus on two kinds of artificial muscle materials:

1. Dielectric elastomer actuators:
   (1) working principle;
   (2) DE materials, DE electrodes, and self-sensing.
2. PVC gel actuators
   (1) working principle;
   (2) preparation of PVC gels, PVC gel electrodes, and self-sensing.

# 1. Wearable assistance applications of DE actuators

Fig. 3 A DE actuator for hand rehabilitation (Reprinted from Carpi et al. (2008), Copyright 2008, with permission from SPIE)

Fig. 4 A DE actuator for lower extremity (human calf) rehabilitation (Reprinted from Pourazadi et al. (2014), Copyright 2014, with permission from IOP Publishing Ltd.)



Carpi F, Mannini A, de Rossi D, 2008. Elastomeric contractile actuators for hand rehabilitation splints. In Electroactive Polymer Actuators and Devices (EAPAD). *Int Soc Opt Photonics*, 6927:692705.

Pourazadi S, Ahmadi S, Menon C, 2014. Towards the development of active compression bandages using dielectric elastomer actuators. *Smart Mat Struct*, 23(6):065007.

# 2. Wearable assistance applications of PVC gel actuators

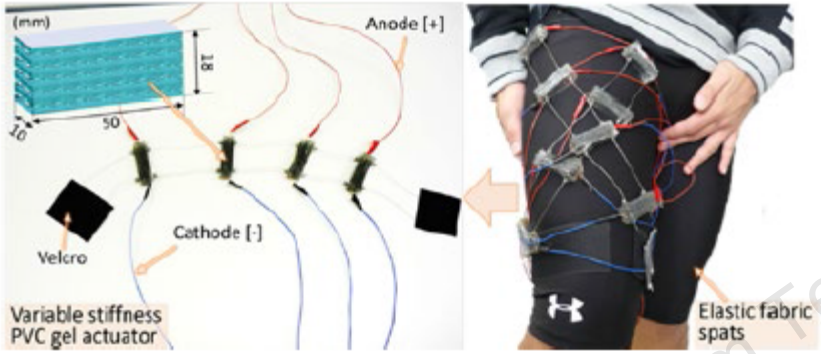


**Fig. 9 A variable stiffness PVC gel actuator for walking assistance (Reprinted from Li et al. (2015), Copyright 2015, with permission from the authors, licensed under CC BY-SA 3.0)**


**Fig. 10 A stretching-type structure PVC gel actuator for walking assistance (Reprinted from Li and Hashimoto (2016), Copyright 2016, with permission from Elsevier)**



Li Y, Maeda Y, Hashimoto M, 2015. Lightweight, soft variable stiffness gel spats for walking assistance. *Int J Adv Rob Syst*, 12(12):175.
Li Y, Hashimoto M, 2016. Design and prototyping of a novel lightweight walking assist wear using PVC gel soft actuators. *Sens Actuat A Phys*, 239:26-44.

# Conclusions

1. A high lower voltage is needed to actuate the two materials, such as reducing the thickness of the material films and adding some fillers during the preparation of the materials, to increase the dielectric constant.

2. The structure of the actuator requires a good design to increase the output force and displacement. The actuator can be tried with applications to human fingers.

3. Self-sensing properties need to be combined with the actuator for good control purposes.