# Chapter 4
# A Soft Robotic Gripper Material Study:
## Effects of CNT Mixing Methodologies

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## ABSTRACT

*Soft robots have gained superiority in outdoor applications compared to traditional robots today. This advantage is clearly due to bio-inspiration and evolving material technology. The objective of this research is to use nanotechnology to improve material qualities. For this, silicone named DragonSkin 20 (DS20), which can be employed in soft robot applications, was selected as the matrix material, while functionalized multi-walled-carbon-nanotube (MWCNT) was utilized as an additive. One of the parameters that determine the mechanical properties is the change of curing behavior. The choice of mixing technique, on the other hand, is very crucial since it affects the curing behavior. For this reason, the effects of not only the additive but also the various mixing techniques on the material behavior and curing time were reported as a result of the experiments. The results showed that the mixing methodologies plays an important role on the mechanical properties and curing time of neat and MWCNT reinforced silicone.*

## INTRODUCTION

Recently, robotic systems have gained importance and become widespread in parallel with technological evolution. They have made people's life easier in many ways, such as increasing safety, time and material savings, and productivity. Also, robots provide advantages in many applications like manufacturing, health care, agriculture, food preparation, military, and electronics (Marechal et al., 2021; Walker et al., 2020; El-Atab et al., 2020)

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A robot is basically classified as hard (rigid) or soft based on its underlying materials (Alici, 2018). Soft robotics which is mostly inspired from biological systems and deals with the control, design, and production of robots consisting of stretchy and flexible materials as opposed to rigid links used in rigid-bodied robots is a subfield of robotics (Lee et al., 2017). While conventional rigid-bodied robots are actuated with rigid electrical motors, hydraulic pumps, or pneumatic compressors (Lee et al., 2017), the movement for soft robots is achieved by using variable-length tendons (Rus and Tolley, 2015) or by pneumatic, hydraulic or twist-and-coil actuators (Pawlowski et al., 2019). Soft robots have many advantages when compared to traditional rigid-bodied robots, such as adaptation to wearable devices, safe-human-machine interaction, and suitability for gripping systems. Besides, conventional rigid-bodied robots are made with aluminum, steel, stainless steel, titanium, etc. which are high stiffness materials. Accordingly, while conventional rigid-bodied robots have limited degrees of freedom, soft robots possess an infinite number of degrees of freedom. However, due to their flexible structure, soft robots are difficult to control because of their inherent deformations, such as twisting, bending, compressing, wrinkling, buckling, and so on (Walker et al., 2020).

Soft robots can be classified by their movements, such as crawling (Cao et al., 2017; Donatelli et al., 2017) and swimming (Marchese et al., 2014; Katzschmann et al., 2015; Ay et al., 2018), or their purpose of usages, such as rehabilitation (Chan et al., 2017; Polygerinos et al., 2015) and grippers (Glick et al. 2018; Zhu et al., 2017). Soft robots are inspired by various biological living creatures. For instance, soft robots that can move by crawling are inspired by animals such as worms, caterpillars, and snakes, whereas soft robots that can move by swimming are inspired by animals such as calamari, octopus, and ink fish. A soft robotic glove is an example of a soft robot used for rehabilitation purposes and used in people with movement disorders. The soft gripper is a new field of gripper technology that is used in pick and place applications by virtue of exploiting its compliance with object interaction. These advancements increase their importance day by day (Yetkin and Koca, 2021).

Recent advancements in rapid digital design and manufacturing tools have been enabled researchers to fabricate soft robotic systems by utilizing adaptable production techniques, including molding, additive manufacturing, thin-film manufacturing, shape deposition manufacturing, and bonding (Gul et al., 2018; Walker et al., 2020). The vast majority of soft robots are made of catalyzed polymers, such as silicone rubbers, which are prepared by mixing two components are generally cast into the mold for fabrication (Marechal et al., 2021).

Since soft robotic systems should perform flexible motion, silicone rubber is mostly used in soft robotics due to its soft and flexible structure. Dragon Skin™ series, Ecoflex™ series, Mold Star™ series, Rebound™ series, Body Double™ series, SORTA-Clear™ series and parts of Sylgard™ series are the most known silicone rubbers, and the characterization of these elastomers has been reported in the literature within the scope of soft robotics (Marechal et al., 2021; El Bana and Abbas, 2020; Presti et al., 2019; Zaltieri et al., 2020).Marechal et al. (2021) focused on the mechanical characterization of seventeen elastomers to aid the researcher to choose proper materials for their applications, namely SORTA-Clear™, Dragon Skin™ 10 MEDIUM, Dragon Skin™ 20, Dragon Skin™ 30, Dragon Skin™ FX-Pro, Dragon Skin™ FX-Pro+Slacker, Body Double™ SILK, Mold Star™ 16 FAST, Mold Star™ 20T, SOLOPLAST 150318, Psycho® Paint, PlatSil® Gel-10, RTV615, Rebound™ 25, Ecoflex™ 00–10, Ecoflex™ 00–30 and Ecoflex™ 00–50. El Bana and Abbas (2020) designed and fabricated a three-finger soft actuator gripper made of Dragon Skin™ 20, which can handle easily fragile and small objects. Presti et al., (2019) dealt with the manufacturing of a fiber Bragg gratings (FBG) based-flexible sensor encapsulated into Dragon Skin™ 20 silicone rubber. The sensor was fabricated with the intention of being utilized in the

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