Chapter 5
New Approaches of Nanocomposite Materials for Electromagnetic Sensors and Robotics

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ABSTRACT

In this paper, the authors define new classes of devices based on nanocomposite materials (NMs). The work introduces approaches about the design and the experimental characterization of these materials. A wide range of applications is presented by discussing novel devices implemented by nanocomposite techniques including sensing and robotic in micro/nano scale. The approaches are oriented on the electromagnetic (EM) characterization of tailored devices such as sensors, and micro/nano antennas. New EM numerical approaches for the design are presented.

1. INTRODUCTION

Polymers such as Su-8 (Lorenz, Despont, Fahrni, LaBianca, Renaud, & Vettiger, 1997; Murillo et al., 2010) polydimethylsiloxane (PDMS) (Cai, Neyer, Kuckuk, & Heise, 2008), polyvinylidene fluoride (PVDF) (Stracanm & Goddard, 2005), polystyrene (PS) (Singer et al., 2008), (PMMA) (Athanassiou, Kalyva, Lakiotaki, Georgiou, & Fotakis, 2003), polyethylmethacrylate-comethylacrylate (PEMMA) (Fragouli et al., 2008), topas (Wang & Soper, 2007), polyvinyl alcohol

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(PVA) (Kancharla & Chen, 2002; Schaper, 2003), polyaniline (De Souza, 2007), polycarbonate (PC) (Chang, Chuang, Ho, & Yarn, 2006), and chitosan (Jiang, Su, Caracci, Bunning, Cooper, & Adams, 1996), are actually commonly used for sensor and actuators. Many researchers are attempting to apply the five senses or artificial muscles (Shahinpoor & Kim, 2004) to intelligent robotic systems. By using these polymers, many kinds of tactile sensors combining small force sensors have been introduced into intelligent robots in order to detect contact force, vibration, texture, and temperature. Future applications of engineered tactile sensors include robotics in medicine for minimally invasive microsurgeries, military uses for dangerous and delicate tasks, and automation in industries. Some tactile sensors and small force sensors using micro electromechanical systems (MEMS) technology have been introduced. MEMS tactile sensing work has been focused mainly on silicon-based sensors that use piezoresistive (Firdaus, Azid, Sidek, Ibrahim, & Hussien, 2010) or capacitive sensing (Lee, Huang, & Chu, 2009). These sensors have been realized with bulk and surface micromachining methods. In this direction, polymer-based devices that use piezoelectric polymer films such as polyvinylidene fluoride (PVDF) (Stracan & Goddard, 2005) for sensing have also been demonstrated (Li, Wu, Shutter, & Narayan, 2010; Kolesar & Dyson, 1995). The piezoelectric effect of PVDF can be also used for energy harvesting applications which include wireless communication network such as energy harvesting implanted systems. Other MEMS implementations are oriented on polymeric materials with metallic/organic micro and nano inclusions. Metallic/organic nanostructures added in polymeric materials generate nanocomposite materials (NMs). In particular, NMs strongly absorb the light becoming technologically interesting, since the light absorbed by the nanostructure can be locally released as heat. Therefore, researchers have utilized strongly absorbing metal nanostructures for a variety of applications, such as localized photothermal ablation treatment of cancer (Hirsch et al., 2006; Hirsch et al., 2003; Huang, El-Sayed, Qian, & El-Sayed, 2006). Conversely, the ability of the metallic nanocomposite to strongly scatter light is critical for optical sensing, tagging and imaging applications (Raschke et al., 2004; Malinksy, Kelly, Schatz, & Duyne, 2001). Applications involving light scattering are numerous, and include the use of metal nanostructures as contrast agents in cancer cell imaging (Sokolov et al., 2003; El-Sayed, Huang, & El-Sayed, 2005), the use of composite metal nanostructures for optical labeling and tagging applications (Mock, Oldenburg, Smith, Schultz, & Schultz, 2002; Nicewarner-Pena et al., 2001; Pompa et al., 2006), and the use of metal nanostructures as optically active strain sensors (Stone, Sisco, Goldsmith, Baxter, & Murphy, 2007). All the above listed NMs applications can be implemented in robotic systems including RF/microwave and radiation applications (Zhuo et al., 2008; Loh & Lynch, 2007). Being some NMs conductive they can be used as antenna radiation systems: the micro/nano metallic particles can be considered as micro/nano probes for detection systems. For this purpose an accurate oriented design tool which predicts the electromagnetic behavior of the probes is necessary. The theoretical prediction represents the basic study of wireless systems for robotics and will be discussed in details in this work together with the approach of the NMs in robotics. The paper is organized as follows: We

- Introduce the nanocomposite sensors by considering some prototypes;
- Explain the approach of the electromagnetic characterization of nanocomposite sensors;
- Finally, we provide a new numerical tool for small antenna sensor design oriented to NMs.
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