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## Nanocomposites, Microfluidics, MEMS and NEMS[1]

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**Summary:**
The focus of this paper is to define a general fabrication and nano-micro-patterning process for polymeric nano-composites which can be electrically conductive, magnetic, or both in nature, and combined with non-doped polymer substrates.

**Keywords:** Polymers, Nanocomposites, Microfluidics, MEMS, NEMS, Micromolding, Hybrid fabrication, Flexible microsystem, Nanoparticles, μTAS, LOC.

**Introduction:** Various elastomers, primarily polydimethylsiloxane (PDMS), a silicone based elastomer, are chosen as substrate materials to create new flexible microsystems because of numerous benefits of PDMS including flexibility, biocompatibility, low cost, low toxicity, high oxidative and thermal stability, optical transparency, low permeability to water, low electrical conductivity, and ease of nano-micro-patterning. However, most devices to date based on PDMS are passive, as making active devices out of PDMS is extremely challenging. When PDMS is bonded to substrates with conventionally-realized active components like electrodes, heaters, sensors, actuators, etc., it is rendered inflexible – defeating one of its key benefits. For example, the common method of bonding PDMS with glass renders the resulting devices completely inflexible. If metals or alloys are deposited on PDMS, the weak adhesion between them and PDMS leads to micro-cracks when the substrates are flexed, bent, or twisted. This leads to electrical disconnection and device failure.

**Solution:** The focus of this paper is the development of novel approaches to the realization of active-component based highly flexible microsystems employing PDMS and/or other elastomer materials. To overcome problems with incorporating active devices while maintaining system flexibility, various new materials and methods of micro-fabricating them are developed. These newly developed electrically conductive and magnetic nano-composite polymers deliver flexibility similar to undoped and insulating PDMS, yet provide functionality for active device development similar to the inclusion of inflexible metals and other functional materials. These new polymers can also be easily micromicromolded using conventional PDMS processing, such as soft lithography techniques. A new hybrid microfabrication process for combining micromolded nanocomposite with undoped PDMS polymer is also developed to demonstrate the potential of the new polymers to be incorporated into fully flexible systems containing active components. Poly(methyl methacrylate) (PMMA) is also explored as a new molding substrate for small and large area microfabrication such that 12 inch by 24 inch flexible sheets containing active nanocomposite polymer devices can be realized on a large scale.

**Applications:** Applications of these multifunctional nanocomposites will be discussed which include shape conformable micro-electrodes for breast cancer detection, smart garments for chronic disease management, hard magnetic micro-actuators, micropumps, signal routing for Lab on a Chip (LOC) and flexible microsystems and electronics.

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[1] Adapted version of authors Ph.D thesis.