Abstract

An electronic sensor skin that can perceive spatiotemporal variation of physical parameters associated with an environment is an integral part of an artificial intelligence system for developing situational awareness. Usually, an electronic sensor skin consists of arrays of many tiny sensors such as pressure sensor, temperature sensor, strain sensor, humidity sensor, etc. Among these sensors, the flexible pressure sensor is an essential part of any electronic skin which allows a machine to interact naturally with its environment. The present study aims to develop membrane based differential pressure sensor skin using MEMS technology for mapping variation of pressure over any surface.

The sensor skin was realized with arrays of pressure sensor micromachined on biocompatible PDMS elastomer. Initially, micromachining of PDMS film was systematically investigated with wet chemical etching for developing MEMS structures and is essential for realizing a membrane-based pressure sensor. Subsequently, thin Au film microstructure was fabricated on PDMS film for developing highly sensitive strain sensitive resistor. As the reliability of a flexible sensor depends on the adhesion between the thin metallic film and underneath polymer film, a self-assembled MPTMS molecular adhesive layer was liquid deposited on PDMS surface. The random buckles developed on the thin metal film was successively oriented by controlled heating without using any ridge surface and prestrain PDMS film. The elemental flexible pressure sensor was first designed for low-pressure sensing range (< 5 kPa) and then simulate in COMSOL Multiphysics software for efficient performance considering PDMS as a nonlinear hyperelastic substrate material. The simulated model was fabricated with microfabrication technology and then characterized for sensitivity, range, hysteresis, response time, power rating, repeatability, RMS noise, and flexibility. Finally, pressure sensor skin was fabricated on the same PDMS platform considering the high degree of flexibility and a lesser number of processing steps using standard fabrication processes. Experimentally, it was observed that sensor skin has very high sensitivity over a range of 0 - 5.5 kPa and can be integrated on a curved surface of radius of curvature as small as 2.3 mm. The pressure field mapping capability of the sensor skin was successfully tested for both static and dynamic pressure field. The dynamic pressure field was created by moving an underwater cylindrical object near the sensor skin. The pressure pulse produced by the moving cylinder was measured by all the pressure sensors in the skin and analyzed for comprehending the dynamics of the pressure field.

Keywords: Flexible electronics, etching, MEMS, microfabrication, MPTMS, PDMS, pressure sensor, situational awareness, sensor skin, thin film.