**Patterning and transferring techniques of graphene-based nanomaterials for flexible and wearable sensor applications**

Flexible electronics and wearable devices have attracted considerable attention due to their mechanical liberty, such as flexibility and stretch ability that can enable the possibility of wide range of applications including invasive structural healthcare monitoring, electronic skin sensing, and energy harvesting. The term of wearable electronics can be defined as devices that can be worn or mated with the sensed surface to monitor the signals continuously without limiting the mechanical deformability of the devices and electronic performance of the functional materials. The use of polymeric substrates (polyimide, polydimethylsiloxane or PDMS) or other nonconventional substrates (e.g., paper, tape, and fabric) as base materials brings novel functionalities to sensors and other electronic devices in terms of being flexible and light weight. Conductive nanomaterials, such as carbon nanotubes, metal oxide nanowires, and graphene were utilized as functional materials for flexible electronics and wearable devices. Specifically, graphene has been searched for producing next-generation sensors due to its impressive electrical and mechanical properties. As a result, incorporation between flexible substrates and graphene- based nanomaterials have been widely utilized to form versatile flexible sensors and other electronic devices through conduction of different fabrication process such as chemical vapor deposition (CVD), mechanical exfoliation, laser scribing, transfer printing, Micro/Nano molding, and ink-jet printing methods.

A large-scale, simple, high-resolution and cost-effective technique is highly demanding to overcome fabrication limitations and provide production of flexible graphene-based sensors. Soft lithography can be merged with mechanical exfoliation process of graphene with adhesive tape followed by transfer printing to form the graphene sensor on desired final substrate. In situ microfluidic casting of graphene into channel is another promising platform that can drive the rapid development of flexible graphene sensors and wearable devices. Selectively coating of graphene-based nanomaterials (e.g. graphene oxide (GO)) on flexible electrode tapes can be used for real-time monitoring of relative humidity (RH) variations at the target surfaces due to its flexibility and adhesive features. This thesis describes the design and development of flexible, stretchable strain, pressure and humidity sensors based on a novel tape-based cost-effective patterning and transferring technique, in situ microfluidic casting method, and a novel selectively coating technique of graphene-based nanomaterials.

 First of all, we present a tape-based graphene patterning and transferring approach which is simple, cost-effective production of graphene sensors on adhesive tapes. The method utilizes the work of adhesion at the interface between two contacting materials as determined by their surface energies to pattern graphene first on PDMS substrate and transfer it onto a target tape. We have achieved patterning and transferring method that outperforms many other counterpart approaches in terms of pattern spatial resolution, thickness control, process simplicity, and diversity with respect to functional materials and pattern geometries. We have demonstrated the usage of tape-based flexible graphene sensors to realize the interaction with structures, humans, and plants for real-time monitoring of important signals.

Secondly, we present a helical spring-like piezo resistive graphene sensor formed within a microfluidic channel by using a unique and easy *in situ* microfluidic casting method. Due to the helical shape, the sensor exhibits a wide dynamic detection range in conjunction with mechanical flexibility and stretch ability. It will enable practical wearable strain sensor applications where large strains are often involved.

Finally, we present a flexible GO-based RH sensor on an adhesive polyimide thin film realized by selectively coating and patterning GO at the surface of Au Interdigitated electrodes (IDEs) and subsequently peeling the device off from a temporary PDMS film. A simple but effective method has been demonstrated to track water transport inside the plant via real-time monitoring of RH variations at the surfaces of different leaves of the plant by GO-based RH sensor. This low-cost method will facilitate studying of water transpiration and transport dynamics in the plant.