In modern society, we cannot imagine a life without electronics. We say hello to friends from afar via e-mail using a computer, listen to music using an iPod while jogging, and take pictures at any time using a digital camera. Inexpensive, mass-produced electronic goods have become such intrinsic parts of our daily lives that, without them, we would feel like cavemen. Without modern electronic devices, we would have to look for a pay phone when we have car accident on the road, search for a signal to listen to music via radio, visit a photo studio to develop the pictures taken with manual film camera, or be subject to inaccurate, primitive medical diagnoses. Inside all these electronic goods – labtops, mp3 players, digital cameras, cell phones, numerous medical devices, and even refrigerators and washing machines, there is a small, marvelous device called a 'thin-film transistor (TFT)'. This small device is the nerve cell of the modern electronic era, which has blessed us with endless benefits. It is an essential component of 21st century civilization.

A TFT device is composed of three essential components – semiconductor, insulator, and conductor (gate, source, and drain) (Figure 1). In this device, electrical current flows in the semiconductor, especially at the interface between semiconductor and insulator, where charge carriers (holes or electrons) accumulates. The insulator blocks unfavorable electrical current flow between semiconductor and gate conductor because current between these two can ruin the device performance. The TFT device acts essentially as electrical current valve, and is controlled by the applied voltage between the conductors (gate and source). To have

efficient, trouble-free electronics, each component in a TFT device must perform its role well. For the last 50 years, TFTs fabricated with inorganic materials such as silicon for the semiconductor, silicon dioxide for the insulator, and metals such as aluminum for the conductors have long dominated electronics. However, these inorganic materials have many limitations which will restrict future applications due to their fragility, high production costs, and incompatibility with low temperature processing.

Given the limitations of conventional inorganic material-based TFTs, the unique characteristics of organic materials offer great promise in numerous applications. Started over 30 years ago with the discovery that organic molecules can act as electrical conductors, this field, '*organic electronics*', is on the verge of the first commercially successful applications. Easy tuning of electronic structure via synthesis, low-cost high throughput manufacturing by printing as one print a newspaper or a magazine, and compatibility with flexible substrates are some of the exciting features of organic electronics. One day soon, these attributes may enable inexpensive radio-frequency ID (RFID) tags which can replace barcodes, cheap printed plastic cell phones, cheap medical diagnostics for the third world, or large-area solar cells painted on building roofs (Figure 2).

Given the promises of organic molecules as TFT components, there have been tremendous efforts over the last decade to develop and improve new organic materials as semiconductors, insulators, and conductors. Especially due to huge recent progress in

organic semiconductors, they exhibit performance comparable to or surpassing those of the common inorganic semiconductors for certain applications.[1] However, for organic insulators, more development for better performance and for understanding how the organic insulator affects the overall device response was needed.[2] Due to solution processibility, low cost, and easy tuning of chemical structure, polymers are the ideal candidates for organic insulators. My thesis research focused on trying to solve the problems associated with polymeric insulators, from both 1) fundamental and 2) application-oriented perspectives in tandem, by elucidating the relationships between polymer architecture and insulator functions using diverse physical measurement tools combined with chemical synthesis.

For the first project, to understand how polymeric insulator properties affect OTFT device performance, I fabricated devices using various polymeric insulators (Figure 3). To systematically compare the effects of various polymer insulators on OTFT performance, especially by their interfacial characteristics, I used bilayer insulators consisting of polymer layer on top of 300 nm silicon dioxide (an excellent insulator by itself) with comparable film thickness and qualities. By employing bilayer insulators and varying the semiconductor deposition temperature, I could investigate the differences between various polymer insulators in terms of their physicochemical and thermal characteristics. As a result, I could conclude that, for controlled/comparable insulator electrical characteristics (possible by using bilayer insulator), chemical nature of various polymer insulators play only a minor role in

OTFT performances.[3] Instead, for the first time in the field, the glass transition temperature at the polymer surface, a precise index of chain viscoelastic properties, was found to have profound effect on the organic semiconductor microstructure growth on top of insulator, eventually the OTFT device performance.[4] Based on this result and related experiments for a variety of polymer architectures, TFT measurements have been demonstrated to represent a new and sensitive methodology to probe polymer surface viscoelastic properties as well as the degree of polymer dielectric film crosslinking.[5,6]

My second project dealt with developing new polymeric insulators having properties uniquely compatible with printing processes. Compared to inorganic insulators, polymers have relatively poor insulating properties, which result in marginal OTFT performance and limited applications. Crosslinking polymer chains with organosilane crosslinkers has been known to form a dense, net-like structure, affords excellent polymeric insulators, possible candidates for printing applications.[7] However, the chlorosilane-based crosslinkers employed in that study are too reactive to control the crosslinking process, and the resulting insulating films have relatively poor surface characteristics. To solve this problem, I conducted experiments using various types of crosslinkers chemically designed and synthesized to alleviate this problem (Figure 4). By using moderately reactive crosslinkers and employing optimized polymer/crosslinker ratios, I obtained 'printable' polymeric insulators with excellent insulating as well as surface properties.[8]

These projects that I've conducted on for less than 4 years were incredibly exciting to me because of the potential for making a real contribution to basic scientific understanding and to electronic technologies that I use everyday. The materials I synthesize and OTFTs I fabricate can serve as the building blocks for completely new applications (Figure 2). In the near future, we may see traffic conditions shown on flexible display embedded in automotive windshields rather than from GPS navigators, check our blood sugar level from plastic sensors attached to our arm without pain from finger poke, or read e-books printed on flexible paper. I believe that my thesis research is going to contribute to shorten the time between when abovementioned benefits are available to serve mankind and the present.

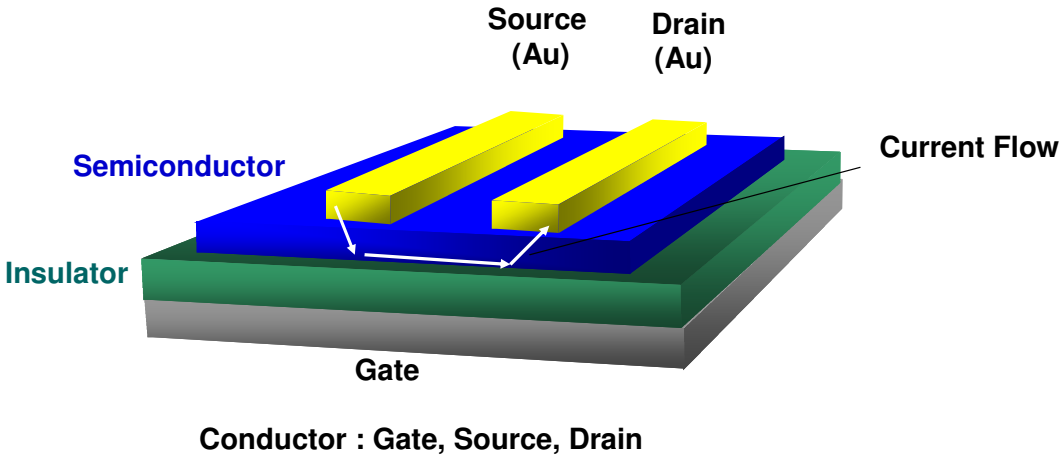

Figure 1. The structure of thin-film transistor. White arrow indicates the current flow in the device.

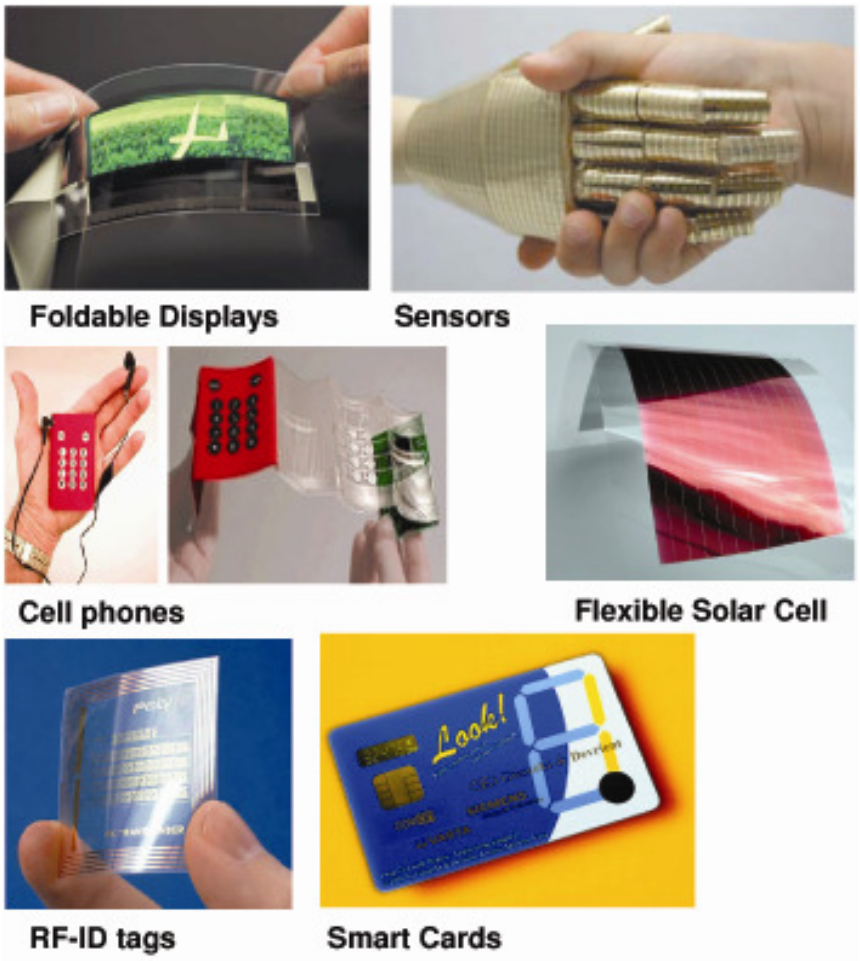

Figure 2. Prototype electronic apparatus based on organic thin-film transistors.

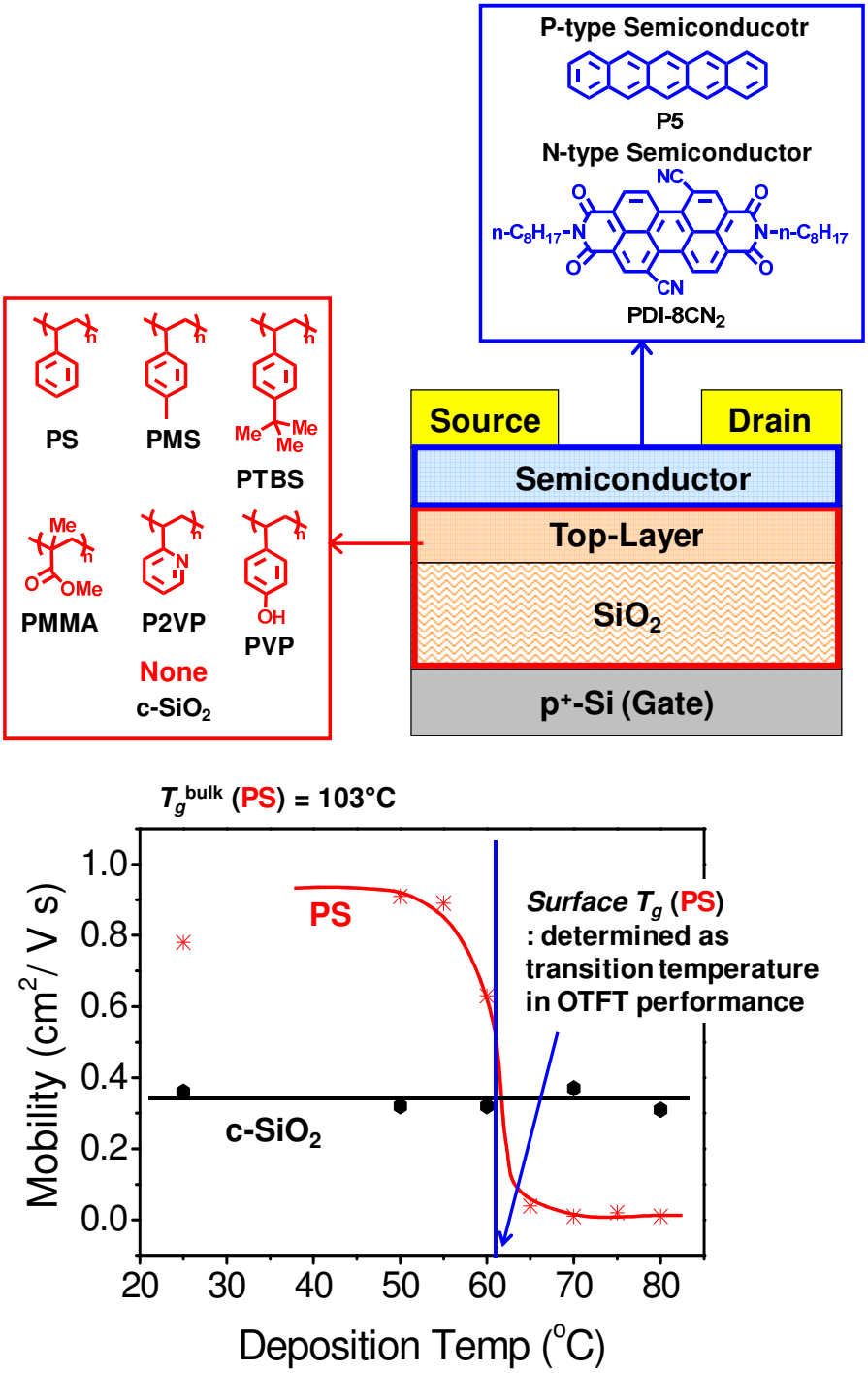

Figure 3. (top) Schematic representation of the top-contact/bottom-gate OTFT structure and the polymer/semiconductor structures employed in the first project of my thesis research. (bottom) Carrier mobility for pentacene (P5)-based OTFTs fabricated at different deposition temperature on polymer bilayer dielectric PS and on c-SiO_2. Surface T_g of the polymer dielectrics was determined as the transition temperature of the carrier mobility.

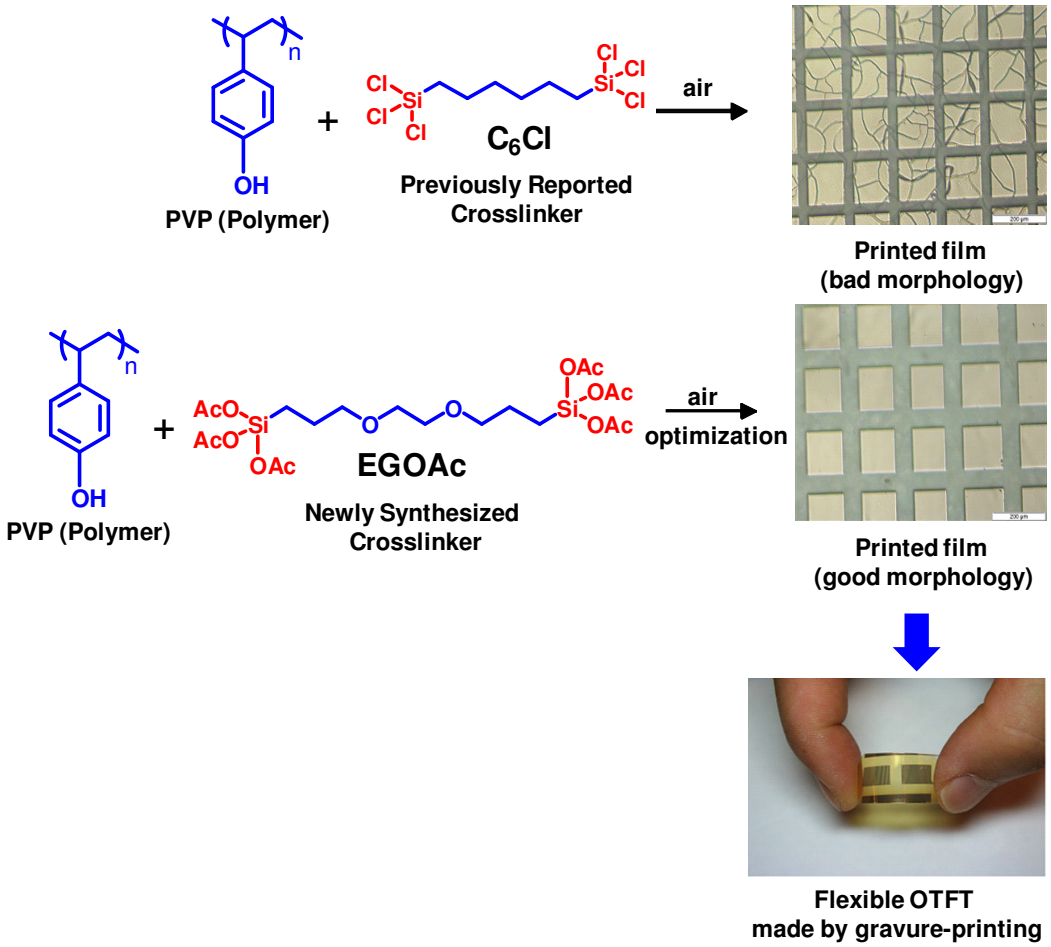

Figure 4. Structures of the polymer and silane crosslinkers (top; previously reported, bottom; newly synthesized) employed and the resulting gravure-printed films/flexible device in the second project of my thesis research.

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