Fiscal Year 2018, Tokyo Institute of Technology ASPIRE League Research Grant

Selected Research Project for Type 1 in FY2018

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Subject	Organic thin film devices based on narrow band gap semiconducting polymers	

Summary of the research project

Narrow band gap semiconducting polymers, implemented in mobile displays, radio frequency identification tags, electronic papers and skins due to their designable synthesis, solution-processability, high thermal stability, and mechanical flexibility, are important materials for future electronic devices. In the past decade, remarkable achievements have been made in polymer thin film transistors (TFTs) with high carrier mobilities over 10 $cm^2 V^{-1} s^{-1}$, which are competitive with or even surpassing the benchmark mobility of amorphous silicon semiconductors.

In order to further increase the carrier mobilities of polymer TFTs, three important polymer design principles are proposed. First, conjugated coplanar backbones with a low conformational disorder must be developed. This enables the formation of short π–π stacking and strong intermolecular interactions in the thin film states. Second, side chain engineering is a powerful tool in increasing the polymer solubility into organic solvents and crystallinity in the thin film states. Third, the introduction of heteroatoms into the π-conjugated backbones results in fine-tuning of energy levels and intermolecular interactions. With these design guidelines in mind, novel semiconducting polymers based on benzobisthiadiazole (BBT) units have been developed by our group. The TFTs based on BBT polymers showed very high mobilities reaching 3.2 $cm^2 V^{-1} s^{-1}$, tunable polarities, and remarkable air stability. Grazing-incidence wide-angle X-ray scattering (GIWAXS) studies of the thin films revealed the importance of the polymer crystallinity and packing orientations. In the ASPIRE League collaborations, these polymers will be applied to high-performance transistors including complementary metal-oxide-semiconductor (CMOS)-like devices, all-polymer solar cells, carbon nanotube (CNT) composite devices, nonvolatile memories, and multi-layer photodiodes. Furthermore, flexibility and mechanical toughness or self-healing properties would be given to these devices.