

Recent Progress of Electro- and Photo-Functional Polymers and Their Applications

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Properties of polymers are strongly dependent on their molecular structures of main chains and substituents in the side chain and also on their morphology. We have studied both insulating polymers with saturated

single bonds in the main chains and also functional polymers with highly conjugated structures either in the main chains or in substituted side chains. Functional polymers can also be realized by introduction of large dipole moments or spins in their structures just as liquid crystalline polymers, ferroelectric polymers and ferromagnetic polymers.

Among various such functional polymers, here, I will discuss mainly functional polymers based on conducting polymers whose main chains are composed of highly extended conjugated electron system. Because of conjugated structures in the main chains, conducting polymers exhibits characteristics as semiconductors and insulators with relatively small band gaps ranging from 0.5eV to 3.5eV depending on their molecular structures.

Substituents and hetero-atoms in the molecular structure, planarity of

conjugation in the main chain and also strength of inter-chain interaction influence strongly on the band gap. This also means that the desired band gap of material can be designed and tailored. The absolute energy levels in electronic states influence also on the electrical properties. It should also be mentioned that because of those relatively small band gap energies, conducting polymers can interact with infrared, visible and ultraviolet lights. As is well known conducting polymers undergo reversible insulator-metal transition upon doping of various acceptor or donor dopants.

These facts suggest that various functional applications of conducting polymers are possible.

Indeed various functional applications of conducting polymers have so far been proposed. We have also proposed and demonstrated various applications of conducting polymers based on our fundamental studies.

Though, among many proposed applications of conducting polymers only several devices such as battery and condenser have been successfully fabricated and sent to market so far, we are convincing that

various other functional applications should also be realized in the industrial scale in the near future. It should also be mentioned that by the introduction of functional molecular units in the side chain, the application of conducting polymers should become more promising.

At the first, we will discuss the properties of conducting polymers as function of molecular structures and show that contrary to common sense so far believed anomalous characteristics appear by the modification of molecular structures.

For example, polyacetylenes have been considered to be non-emissive and their characteristics can be explained by soliton model.

However, we have demonstrated that in disubstituted polyacetylenes strong photoluminescence (PL) is observed and their emission characteristics such as wavelength of PL and efficiency are dependent on the structures of substituents. For example, intense green PL and blue PL were observed in poly(dephenylacetylene) (PDPA) and poly(1-alkyl2-phenyl acetylene) (PAPA) and their intensity increases with increasing with increasing alkyl chain length or by introduction of bulky substituents.

Except for fundamental research we have also studied electroluminescence (EL) in conducting polymers in the device with the structure of cathode / conducting polymer / anode. In most cases as anode ITO was used and as cathode either MgIn alloy or aluminum (Al) were used. We have demonstrated red, green and blue ELs utilizing

polythiophene derivatives, poly(p-phenylenevinylene) derivatives and polyfluorene derivatives for examples. We have also show that polyacetylene derivatives PDPA and PAPA also exhibits strong green and blue ELs. Except for common structure of EL devices, we indicated that polarized EL can be realized utilizing a device fabricated with oriented conducting polymer prepared by quite simple rubbing method. Color variable EL devices were also demonstrated utilizing multilayered structure of devices, in which emission color depends on the polarity of applied voltage. Electrochemical EL devices were also reported by us. Highly efficient PL and EL suggest the possibility of lasing in conducting polymers.

We have studied photo-modulation spectroscopy in conducting polymer and revealed photo-induced absorption and stimulated emission in the spectrum.

Dynamics of excitons in conducting polymers have also be studied. In these studied we convinced the possibility of lasing in conducting polymers. We have demonstrated remarkable spectral narrowing of emission upon optical excitation at relatively low excitation level in various conducting polymers such as poly(2,5-dialkoxyphenylenevinylene)s, PDPA, PAPA and polyfluorene derivatives in films. The observed spectral narrowing are discussed in terms of superradiation, superfluorescence and amplified spontaneous emission.

By forming micro-ring cavity either by covering surface of glass

fibers of micron-meter scale in diameter with conducting polymer, laser emission with spectral width less than 1nm and extremely low threshold of optical excitation less than 0.1 nJ/cm² was demonstrated and explained either by wave-guided mode or gallery whispering mode.

We have also demonstrated cylindrical structure of EL device with Al/conducting polymer/ITO coated fiber.

We found liquid crystalline behavior in poly(2,5-dialkoxyphenylenevinylene) such as poly(2,5-dinonyloxyphenylenevinylene) whose main chain has rigid structure contrary of conventional polymer liquid crystals with flexible main chains. It should also be mentioned that upon introduction of substituents containing mesogen units in the side chain of poly(p-phenylenevinylene) conducting polymer liquid crystal was realized in which EL was also observed.

Various other functional applications such as new concept of photo-voltaic devices utilizing conducting polymer and C60 and also p-type and n-type conducting polymers have been proposed and their novel characteristics have been demonstrated.

Some of our recent activities in the field of fundamental study and applications of functional polymers such as conducting polymers are included in following recent publication lists.

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He is one of the pioneer in the field of conducting polymer and has made remarkable contribution for the progress of understanding of fundamental process and applications of conducting polymers. He published more than 800 papers and authored, co-authored or edited 30 books. He organized and is organizing several international conferences such as 1986 International Conference of Science and Technology of Synthetic Metals and 13th International Conference on Dielectric Liquids in 1999. He has contributed a lot as director of many academic Societies. He was a vice president of the Institute of Electrical Engineers of Japan.

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