Effect of light irradiation on charge carrier dynamics in active layer hybrid solar cells

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Solar power generation is a key method for generating electronic power. Several researchers have attempted to achieve higher performance of the solar cells and more effective materials for use in cells. The discovery of conjugated polymers, such as Polythiophene (PT) and its derivatives, attracted much attention owing to their chemical and thermal stability as well as their potential use as an absorbing solar spectrum material (active layer) in solar cells. The most necessary property of these active layers is their ability to transfer the charge carrier resulting from the absorption of solar spectrum. In particular, Poly(3-hexylthiophene)/P3HT has considerable research interest, because it shows the highest hole mobility among the series of Poly(3-alkylthiophene).[1)] In our previous muon Spin Relaxation (μSR) study, the charge carrier mobility in P3HT was found to change from one-dimensional to a three-dimensional model, which is strongly dependent on their molecular structure and temperature.[2,3)]

Recently, the so-called hybrid (organic-inorganic) solar cell was developed owing to the combined advantage between organic material (P3HT) and inorganic material such as ZnO, which ensures better performance for practical application. ZnO is inorganic material with high electron mobility and can be easily prepared as electron acceptor to dissociate excitons formed in conjugated polymer as the active material of solar cells. ZnO can be prepared as a nanoparticle that can resolve the problem of small diffusion range of P3HT.[4)] The existence of ZnO in active layer will support charge transfer from P3HT to electrode of solar cell because the conduction band of ZnO is lower than that of low unoccupied molecular orbital (LUMO) of P3HT.

We studied the microscopic intrinsic charge carrier dynamics in active material of P3HT:ZnO along and perpendicular to the chain by using the longitudinal field (LF) μSR method. We found that the charge carrier mobility changes from intrachain to interchain diffusion above 25 K for P3HT:ZnO. We also have measured charge carrier dynamics of P3HT:ZnO with light irradiation. Figure 1 shows the asymmetry data of P3HT:ZnO at 10, 15, 25, and 300 K for various longitudinal magnetic field values with (red data) and without (black data) light irradiation. We found small changes of asymmetry when light irradiation on condition and off condition, however we cannot observe significant effect probably due to low intensity of light irradiation.

Figure 2 show the longitudinal-field dependence of relaxation rate λ_1 of P3HT:ZnO nanoparticles at 10, 15, 25, and 300 K. Without light irradiation, for the lowest temperature of 10 K, $\lambda \sim H^{-0.5}$ is clearly displayed indicating one-dimensional intra-chain diffusion. In contrast, for the same temperature, light irradiation displayed $\lambda \sim C - H^{0.5}$ curve, indicating three-dimensional inter-chain diffusion. Thus, it is clearly seen that with light irradiation, temperature crossover occurred from one-dimensional to three-dimensional at the lower temperature of 10 K compared to that in a previous result at 25 K.[5)]

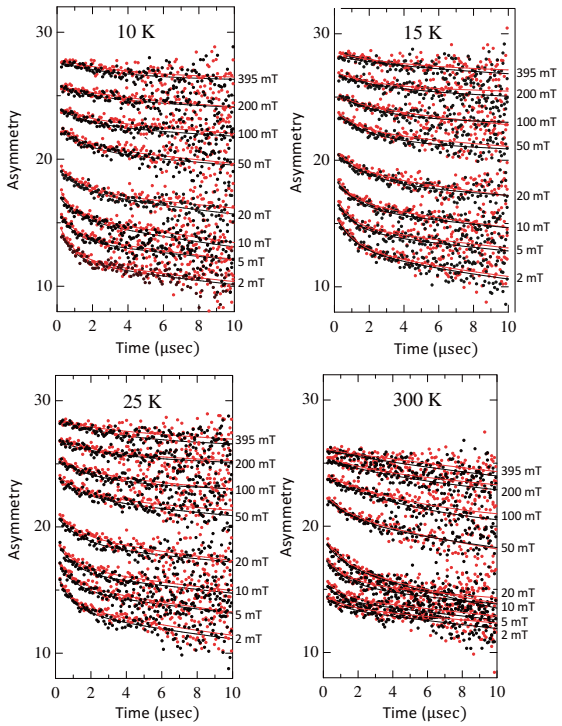

Fig. 1. The asymmetry data of P3HT:ZnO at 10, 15, 25, and 300 K for various longitudinal magnetic field values.

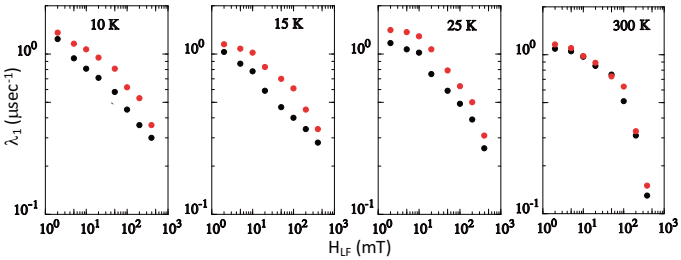

Fig. 2. The longitudinal-field $H_{\rm LF}$ dependence of relaxation rate λ_1 of P3HT:ZnO nanoparticles at 10, 15, 25, and 300 K.

References

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