INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Trap Assisted Organic Semiconductors for Non-Volatile Resistive Random Access Memory Device: Design, Simulations and Experimental Investigations

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Since the evolution of computational technology, memory devices have become one of the most indivisible part of any on-chip computing devices. The recent boom in the big data market and the progress in the Internet of Things (IoT) have nourished the demand for semiconducting memories. Inorganic memory devices have some technological limitations compared to organic memory devices that are expected to be one of the propitious candidates due to their wide advantages like low cost, easy fabrication, low temperature processing, biocompatibility and flexibility. In spite of the promising features, two terminal memory device fabricated using organic materials contain several challenges and remains to be addressed for commercialization. First of all the mechanism behind the switching characteristics in an organic memory devices are not clearly understood. Secondly, inorganic material were always required along with the organic materials in fabricating the active layers of the organic memory device. Though all-organic active layer containing donor-acceptor (D-A) molecules exhibit switching characteristics, the tunability of the memory parameters are not explored very much. Lastly, unlike its counterpart, organic memory devices are not very much used in neuromorphic applications due to its classic binary switching characteristics. This thesis broadly addresses the above challenges with the help of certain state-of-the-art techniques. This thesis is broadly categorized into three parts based on the materials, switching mechanism and the application of the trap controlled organic memory using doping technology. The first part focuses on developing new materials and strategies towards an all organic memory device. D-A polymer containing polyfluorene (PFO) as donor and naphthalimide (NPN) derivative as acceptor is synthesized and fabricated as single active layer in a two terminal memory device which exhibits remarkably high Ion/Ioff ratio of 108. Moreover the PFONPN molecule assists in tunability, where the memory parameters can be varied by changing the concentration of acceptor moiety with respect to donor unit. Further, with an intention to create an all organic memory device, the classic method of including an inorganic material into an organic semiconductor matrix is revoked by designing an organic nanoparticle by reprecipitation of a naphthalimide derivative that are embedded into a polymer matrix. The all organic active layer exhibits an Ion/Ioff ratio of 103 with very good endurance and repeatability. In the second part of the thesis, the switching characteristics of the trap containing memory device is mechanically investigated using kinetic Monte Carlo (KMC) algorithm to clearly understand the reason for the switching characteristics. The ab initio modelling and simulation reveals that Coulomb blockade effect induced by the dopants plays a substantial role in exhibiting the switching characteristics of the memory device and the physical insights from the results of the simulation provides architectural and material guidelines to achieve a highly efficient memory device. Finally, the organic memory devices are further exploited for advanced applications like artificial intelligence (AI). A ferroelectric polymer doped with lithium salt was utilized as an active layer of the memory device that exhibits an analog type switching characteristics, which are helpful to mimic an artificial synapse. The device successfully emulates various characteristics of a biological synapse like potentiation, depression, short term plasticity to long term plasticity, Learning-forgetting-relearning and paired pulse facilitation. The contribution of this thesis towards the theoretical understanding and the practical implementation of the memory device provides the basis for facilitating the commercialization of the organic memory devices in the near future.