THESIS DEFENCE

Speaker: Ms. Deepa Singh

Title: "Approaches for improving ferroelectric properties of P(VDF-TrFE) for flexible memory devices" according to the following schedule

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Abstract: Non-volatile memory (NVM) devices based on ferroelectric thin films show bistable polarization at zero bias, designated as '0' and '1' logic states. Current emphasis on developing flexible and large area devices requires the use of polymeric and organic materials. This makes organic ferroelectric polymers such as poly(vinylidenefluoride-trifluoroethylene)(P(VDF-TrFE) worth exploring due to their low temperature solution processibility. The optimum performance of a ferroelectric NVM device needs a remnant polarization of over 4-5 μC/cm2, a low operating voltage and low leakage current, preferably below 1E-9 A/cm2. Overall, the aim of the work is to understand the growth of P(VDF-TrFE) thin films and develop strategies to improve the ferroelectric devices behavior for memory applications.

Typically, the P(VDF-TrFE) films are spin coated and then annealed between their curie and melting temperatures. In the first part of this work, we have investigated rate of cooling P(VDF-TrFE) after annealing and nature of the top electrode in the capacitor. The cooling rate severely influences the film formation characteristics and growth mechanisms and the consequent ferroelectric and electrical properties of the films. While the published literature is based on natural cooling of the films, we suggest a fast cooling process, for example, cooling in ice water, which leads to P(VDF-TrFE) thin films with higher fraction of the β-phase, necessary for ferroelectric nature of P(VDF-TrFE). The result is an increased polarization by 30%, decreased coercivity by 60% and reduced electrical leakage in capacitive memory devices. Nonetheless, the electrical leakage current in the capacitor still needs to be reduced.

For further reduction of electrical leakage in the P(VDF-TrFE) devices, we incorporated PMMA, a dielectric material, along with P(VDF-TrFE) in different amounts in three different configurations: in the form of blend, and two bilayer structures, one with PMMA films below P(VDF-TrFE) films and another with PMMA films on top of P(VDF-TrFE) films. We find that PMMA incorporation leads to nearly two orders of magnitude reduction in the electrical leakage rendering bilayer devices more suitable for device applications than P(VDF-TrFE) only devices. Specifically, 60 nm PMMA on 140 nm P(VDF-TrFE) led to a smother dielectric stack with remanent polarization between 4-6 μC/cm2. The organic ferroelectric field effect transistor (FeFET) devices fabricated by thermally evaporating the semiconducting channel of pentacene on the smooth P(VDF-TrFE)/PMMA films showed enhanced electrical characteristics, marked by a large drain to source current at lower gate voltage, with promising non-volatile memory functionality.

Next, we investigated electro-mechanical fatigue characteristics of the thin film devices on flexible substrates. The flexible electronic devices require the thin film components of the stack to withstand the stress levels induced by mechanical bending. We demonstrate that the P(VDF-TrFE) capacitors

fabricated on flexible substrates exhibit almost no change in the ferroelectric behaviour up to 30000 bending cycles, tested with a bending radius of 0.6 cm. Further, we also investigated the fatigue endurance of ferroelectric capacitors against the bipolar electric field switching. The results suggested that the onset of degradation of polarization occurs at 104 electrical cycles. The likely reason behind this degradation appears to be permanent phase decomposition from ferroelectric phase to a non ferroelectric phase due to HF formation as verified using micro-FTIR spectroscopy.

Finally, we have examined the effect of various solvents with different dipole moments on charactersitcs of P(VDF-TrFE) film capacitors from the perspective of improving the ferroelectric response further, especially the coercivity for achieveing low voltage operation of the devices. The results showed that the solvents with large dipole moment yield larger polarization at lower voltages and a much improved electrical fatigue behaviour, especially when the substrates are UV ozone treated. Surprisingly, when we use a mixture of methyl ethyl ketone and dimethyl-sulphoxide as a solvent to fabricate P(VDF-TrFE) films, electrical fatigue free ferroelectric capacitor became fatigue free with excellent piezoelectric properties and thermal stability up to 390K.