PREFACE

Thin-film transistors (TFTs) are the prime elements for accelerating the development of flat-panel displays (FPDs) applications, especially emergence of both active matrix liquid crystal displays (AMLCDs) and active matrix light emitting diode (AMLEDs) displays. In modern days, higher resolution, larger screen size and lower power consumption in the FPDs have been an immense requirement, which has pressed the traditional amorphous Si (a-Si) TFTs technology to its limits. On the other hand, metal-oxide TFTs have been extensively studied for various applications including phototransistor, biosensors arrays, gas, pressure sensors, light emitting transistors and photo-detectors, etc. Since, metal oxide TFTs are now expected to be one of the most promising technologies for next-generation display technologies, because of their high carrier mobility, good transparency, excellent uniformity and reasonable electrical reliability/stability. Over the previous decades, SiO_2 is the standard gate dielectric material because it makes the defect-free and high-quality film (free from the pinhole and impurities) in the form of native oxide with silicon substrates which deposited through thermally grown and vacuum deposited based on most of the reported results. However, most of these TFTs require high operating voltages ($\geq$40V) due to the low dielectric constant (k) of conventional SiO_2 gate dielectric which is commonly used for metal oxide TFT, limiting its application to portable low power electronics. For the demand of high-performance devices for portable electronics (e.g., laptop, tablet, mobile, etc.) maintaining the low power consumption, core unit size, i.e., field effect transistors (FETs) have been notably scaled down. Metal oxide TFTs by conventional vacuum-based technologies have been well established and have gone to commercialization in a short period. However, the high cost of necessary equipment and restriction of deposition on a relatively small area have limited their potential applications in large-area electronics. On the contrary, the solution process has many advantages, including large-area fabrication, equipment simplicity, roll-to-roll capability, atmospheric processing, and low-cost setup, which is beneficial for academic and industrial research purpose.

Previously, several efforts have been made for developing low voltage with low power TFTs like ion-gel self-assembled layer and ion conducting metal oxide (ICMO), etc. However, for low voltage operation, ICMO is considered much better material than those metal oxide insulators because of their high environmental and thermal stability. ICMO dielectric is the emerging class of smart materials which can produce high capacitance because of the existence of mobile lightweight ion (like Li^+, Na^+, $K^{+,}$ etc.) of crystalline dielectric materials. This ionic shifting provides the interfacial/electric double layer (EDL) capacitance which gives the low operating voltage for the metal oxide TFT by maintaining the high mobility and on/off ratio of the device. Alternatively, Pal et al. first gave a new approach by incorporating alkali metal into metal oxides (MO_x) lattices to enhance the k value of host dielectric material. Sodium-beta alumina is the first ICMO dielectric that successfully utilized as a gate dielectric in low voltage TFT.

In this search, we have identified a popular ion conducting electrolyte for Li^+ ion battery that can be grown in a crystalline form by sol-gel technique at low processing temperature, is the central interest of my thesis work. Application of this lower processing temperature ion-conducting dielectric materials used as a gate dielectric in the low operating voltage transistor, which will be beneficial for low power consuming portable devices. Our detailed investigation on the development of different ion-conducting gate dielectric reveals several important finding which is not previously reported.

In this thesis, we have developed two new ion-conducting electronic insulators by the low-cost sol-gel route and successfully utilized as a gate dielectric for a low voltage TFTs. These two ion-conducting oxides are Li_5AlO_4 and $LiAlO_2$. In these dielectrics, Aluminum and oxygen atoms are in tetrahedral position and connected to the lithium ion. This dielectric forms interstitial Li^+ ion that shows high ionic conductivity arising from the partially occupied site in $LiAlO_2$. Because of this Li^+ ion conductivity, it becomes possible to fabricate a high capacitive thin film with both of these two ion-conducting insulators, which is an important factor for the development of low voltage TFT. Finally, using these dielectrics, the high-performance transistor was fabricated that has a 2.0 V operating voltage with the high mobility and good on/off ratio.

In TFT, accumulation of mobile charge carrier in semiconductor/dielectric interface is directly proportional to the capacitance and higher capacitive gate dielectric film requires low voltage to accumulate the desired amount of carrier in the channel. In ICMO, Li^+ ion is free to move through the crystal lattice plane that gets accumulated in either surface based on the polarity of external bias and contributes additional ionic polarization to introduce a high capacitive effect. Apart from this high capacitance effect, the leakage current density and dielectric interfaces are also important issues for a high-quality gate dielectric. The $LiAlO_2$ is a unique solid-state electrolyte that has very good ion conductivity with very poor electron conductivity, serving as a good electronic insulator. Moreover, crystalline $LiAlO_2$ can be synthesized at a lower temperature like 350 ^oC, which is within the range of allowed display fabrication.

Using this ion conducting dielectric with the bilayer structure, we have been enhanced the TFT performance like, improved the subthreshold swing, reduced the interfaces states, higher the mobility and on/off ratio. High-performance solution-processed one-volt metal oxide TFT has been fabricated onto highly p-doped silicon (p^{++}-Si) substrate with sol-gel derived ion-conducting gate dielectric by using electron donating TiO_2 gate interface. Comparative electrical characterization of two different TFTs with TiO_2, Al_2O_3 gate interface device reveals that n-type TiO_2 works as an electron donor to the semiconductor/dielectric interface trap state. As a consequence, sub-threshold swing (SS) of the TiO_2 interface device reduces significantly by keeping threshold voltage closer to zero, enabling to achieve significantly higher performance one-volt TFT with respect to 'without TiO_2' and 'with Al_2O_3' interface devices**.** Depleted layer of p^+-Si(111)/TiO_2 interface reduces gate leakage current significantly that helps to improve the on/off ratio and subthreshold swing of the device. This investigation provides a feasible direction towards the development of high-performance, low voltage TFT fabrication with various materials combination.

At the end of the thesis, we discussed the main findings of the present work and listed a few suggestions for future investigations.

List of journals and books used to bind up the thesis has been given at the end of the thesis as references.