Impact of $\text{Al}_2\text{O}_3$ Gate Dielectric on the Low-Frequency Noise in InGaZnO Thin-Film Transistors

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I. INTRODUCTION

Metal oxide semiconductor thin-film transistors (TFTs), in particular amorphous indium gallium zinc oxide (a-IGZO) TFTs, have attracted interest for display and flexible electronics applications due to their good electrical characteristics and low deposition temperatures [1]. For analog circuit applications, noise is an important issue to be considered as it sets the limit of the signal that can be detected. High-k dielectrics have the potential to improve device performance, but this has been limited by high defect density in the dielectric and dielectric/channel interface [2]–[5]. To remediate this, $\text{SiO}_2$ has been employed as an interfacial dielectric in between the semiconductor and the high-k dielectric in order to improve the interface quality [3], [4], however this comes with an increase in the number of fabrication steps. In this work, we present a comparative study of the low frequency noise (LFN) behavior of a-IGZO TFTs fabricated with $\text{SiO}_2$ and $\text{Al}_2\text{O}_3$ as gate dielectric, without the use of any interfacial dielectric layer.

II. EXPERIMENTAL RESULTS AND DISCUSSION

Top-Gate Self-Aligned (SA) TFTs with 20 nm-thick low temperature atomic layer deposition (ALD) $\text{Al}_2\text{O}_3$ as gate dielectric were fabricated and compared with TFTs with 100 nm-thick plasma-enhanced chemical vapor deposition $\text{SiO}_2$ gate dielectric [6]. As shown in Fig. 1(a), the LFN in both devices follows the expected $1/f$ noise spectrum, with $\gamma=0.9$–1.1 in the frequency range of 1 Hz to 1 kHz. The normalized drain current noise power spectral density (PSD) ($S_{iD}/I_{th}^2$) of the $\text{Al}_2\text{O}_3$ TFT is more than 20 times lower than that of the $\text{SiO}_2$ TFT when biased in the linear regime.

The dominating noise mechanism can be identified by evaluating the dependence of $S_{iD}/I_{th}^2$ on the gate overdrive voltage at a fixed frequency [7]. Fig. 1(b) illustrates that $S_{iD}/I_{th}^2$ has a power law dependence on $(V_{gs}−V_{th})^m$, with $m=1.1$ and $m=0.9$ for $\text{SiO}_2$ and $\text{Al}_2\text{O}_3$ TFTs respectively. $S_{iD}/I_{th}^2$ increases for higher bias voltages, which indicates that the noise from the source/drain contacts starts to be dominant. A value of $m$ near to -1 is in close agreement with the mobility fluctuation model, a theory that proposes that the main noise contribution stems from carrier-phonon scattering [8]. Using this model, we extracted the Hooge’s parameter ($\alpha_H$) for the studied TFTs, Fig. 1(c). For the TFT with $\text{SiO}_2$ gate dielectric the value is $~3.9 \times 10^{-3}$, in agreement with literature [7]. For the one with $\text{Al}_2\text{O}_3$ gate dielectric, the Hooge’s parameter is $~1.3 \times 10^{-3}$, a value 3 orders of magnitude lower than the ones previously reported [3].

The dependence of $S_{iD}/I_{th}^2$ on gate bias indicates that the mobility fluctuation is the dominant noise source in both devices. It is reasonable to assume that due to the amorphous nature of the semiconductor, bulk processes dominate the noise behavior. This, combined with the fact that the extracted Hooge’s parameters are comparable for both dielectrics, suggests that the dielectric and the dielectric/channel interface play a lesser role in the LFN of the studied devices. The obtained $\alpha_H$ is the lowest one reported for an a-IGZO TFT using only a high-k gate dielectric without the use of an interfacial layer, Fig1(d). This result demonstrates that using $\text{Al}_2\text{O}_3$ as gate dielectric does not necessarily cause a detrimental effect in the LFN of a-IGZO TFTs.

REFERENCES