Encapsulation for IGZO Thin Film Transistors

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I. Project Goal

Goal: To investigate the effectiveness of several materials as encapsulation to improve thermal stability in Indium-Gallium-Zinc Oxide TFTs.

An effective encapsulation material:
- Behaves like a hermetic seal
- Does not degrade standard device operation
- Shows resistance to thermal stress testing

II. Motivation

TFTs are used in LCD display technologies and can be made of a-Si:H (low mobility), poly-Si (higher mobility but expensive), or IGZO.

IGZO benefits:
- Higher mobility than a-Si
- Less expensive than poly-Si
- Compatible with existing process lines

III. Hypothesis for Thermal Instability

- PECVD SiO2 readily adsorbs moisture present in the room ambient
- During thermal stress, the absorbed water reacts with IGZO surface/bulk, raising the electron concentration (donor effect)
- For DG devices, H2O in oxide reacts with Al to form Al2O3 which liberates monatomic hydrogen and a larger VT shift is observed
- The same mechanism is operative during sintering of Si-MOS devices resulting in interface traps passivation [1]

IV. Proposed Solution

Use an atomic-layer deposited (ALD) material to act as an encapsulation layer/barrier to the water vapors present in the ambient.

Proposed ALD materials:
- Aluminum oxide (Al2O3)
- Hafnium dioxide (HfO2)
- Titanium dioxide (TiO2)
- Nano-laminate (Al2O3/HfO2)

Nano-laminate: alternating 5nm layers of two or more ALD materials. This is used to decrease the chance of defects in the ALD film which decreases the probability of ambient H2O diffusing into the IGZO.

V. I-V Characteristics

Figures 4-8 show that the addition of an encapsulation layer significantly improves the thermal stability of IGZO TFTs. This effect can be seen in both BG and DG devices however, DG HfO2 devices seem to show slightly better stability.

VI. Conclusions

Bottom gate devices without encapsulation exhibit a shift of about 2 V under a thermal stress for 120 min at 140°C. After encapsulation the shift is reduced to about 0.5 V. Double gate devices without any encapsulation show a shift of 7 V at 140°C after 120 min while devices with encapsulation show no apparent shift. When subjected to 200°C for 60 min, encapsulated bottom gate devices show a minimal voltage shift while devices without encapsulation show a shift of about 4 V. All double gate devices subjected to 200°C for 60 min become conductive (i.e. resistors). This study confirms the hypothesis that the water incorporation in TEOS oxide is responsible for instability after thermal treatment. ALD deposited Al2O3 and HfO2 films are excellent barriers to moisture and application of these films over the fabricated devices demonstrate significant improvement in stability.

Future Work

- DG Al2O3 device testing
- TiO2/Nano-laminate encapsulation

References


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