

Fabricating stable, high-mobility transistors for next-generation display technologies

December 16 2021

Overcoming the Mobility–Stability Trade-off in Thin-Film Transistors

Amorphous oxide semiconductor (AOS) thin-film transistors (TFTs) are promising materials for flat-panel displays

But, TFTs show a trade-off between electron mobility and gate-bias stress stability

Overcoming high mobility–low stability trade-off in indium tin zinc oxide (ITZO) TFTs

	13	Al	14	Si
		Aluminium		Silicon
30	Zn	Ga	32	Ge
	Zinc	Gallium		Germanium
48	Cd	In	50	Sn
	Cadmium	Indium		Tin

High mobility ↓
Deep CBM

High mobility Low mobility

CBM Small barrier CBM Large barrier

VBM VBM

Trade-off due to

- ✓ Conduction band minimum (CBM) location
- ✓ Relevant doping ability

Low stability due to impurities, such as carbon monoxide (CO)

Ultrastable, high-mobility ITZO TFT by removing CO impurities

These results pave the way for future fabrication of ultrastable high-mobility AOS TFTs for commercial applications in display panels and more

Mobility–stability trade-off in oxide thin-film transistors
 Shiah et al. (2021) | Nature Electronics | DOI: 10.1038/s41928-021-00671-0



Credit: Tokyo Institute of Technology

The trade-off between carrier mobility and stability in amorphous oxide semiconductor-based thin film transistors (TFTs) has been finally overcome by researchers from Tokyo Institute of Technology (Tokyo Tech) in an ingeniously fabricated indium tin zinc oxide TFT. This could pave the way for the design of display technologies that are cheaper than current silicon-based technologies.

Amorphous oxide semiconductors (AOS) are a promising option for the next generation of display technologies due to their low costs and high electron (charge carrier) mobility. The high mobility, in particular, is essential for high-speed images. But AOSs also have a distinct drawback that is hampering their commercialization—the mobility–stability tradeoff.

One of the core tests of stability in TFTs is the negative-bias temperature stress (NBTS) stability test. Two AOS TFTs of interest are indium gallium zinc oxide (IGZO) and indium tin zinc oxide (ITZO). IGZO TFTs have high NBTS stability but poor mobility while ITZO TFTs have the opposite characteristics. The existence of this tradeoff is well-known, but thus far there has been no understanding of why it occurs.

In a recent study published in *Nature Electronics*, a team of scientists from Japan have now reported a solution to this tradeoff. "In our study, we focused on NBTS stability which is conventionally explained using 'charge trapping.' This describes the loss of accumulated charge into the underlying substrate. However, we doubted if this could explain the differences we see in IGZO and ITZO TFTs, so instead we focused on the possibility of a change in carrier density or Fermi level shift in the AOS itself," explains Assistant Professor Junghwan Kim of Tokyo Tech,

who headed the study.

To investigate the NBTS stability, the team used a "bottom-gate TFT with a bilayer active-channel structure" comprising an NBTS-stable AOS (IGZO) layer and an NBTS-unstable AOS (ITZO) layer. They then characterized the TFT and compared the results with device simulations performed using the charge-trapping and the Fermi-level shift models.

They found that the experimental data agreed with the Fermi-level shift model. "Once we had this information, the next question was, "What is the major factor controlling mobility in AOSs?" says Prof. Kim.

The fabrication of AOS TFTs introduces impurities, including [carbon monoxide](#) (CO), into the TFT, especially in the ITZO case. The team found that charge transfer was occurring between the AOSs and the unintended impurities. In this case the CO impurities were donating electrons into the active layer of the TFT, which caused the Fermi-level shift and NBTS instability. "The mechanism of this CO-based electron donation is dependent on the location of the conduction band minimum, which is why you see it in high-mobility TFTs such as ITZO but not in IGZO," elaborates Prof. Kim.

Armed with this knowledge, the researchers developed an ITZO TFT without CO impurities by treating the TFT at 400°C and found that it was NBTS stable. "Super-high vision technologies need TFTs with an electron mobility above $40 \text{ cm}^2 (\text{Vs})^{-1}$. By eliminating the CO impurities, we were able to fabricate an ITZO TFT with a mobility as high as $70 \text{ cm}^2 (\text{Vs})^{-1}$," comments an excited Prof. Kim.

However, CO impurities alone do not cause instability. "Any [impurity](#) that induces a charge transfer with AOSs can cause gate-bias instability. To achieve [high-mobility](#) oxide TFTs, we need contributions from the industrial side to clarify all possible origins for impurities," asserts Prof.

Kim.

The results could pave the way for fabrication of other similar AOS TFTs for use in display technologies, as well as chip input/output devices, image sensors and power systems. Moreover, given their low cost, they might even replace more expensive silicon-based technologies.

More information: Yu-Shien Shiah et al, Mobility–stability trade-off in oxide thin-film transistors, *Nature Electronics* (2021). [DOI: 10.1038/s41928-021-00671-0](https://doi.org/10.1038/s41928-021-00671-0)

Provided by Tokyo Institute of Technology

Citation: Fabricating stable, high-mobility transistors for next-generation display technologies (2021, December 16) retrieved 23 April 2024 from <https://techxplore.com/news/2021-12-fabricating-stable-high-mobility-transistors-next-generation.html>

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