The 17th ROK-USA Forum on Nanotechnology

Highly Reliable Organic Non-Volatile Memory Devices Based-on Hybrid Films via iCVD Process

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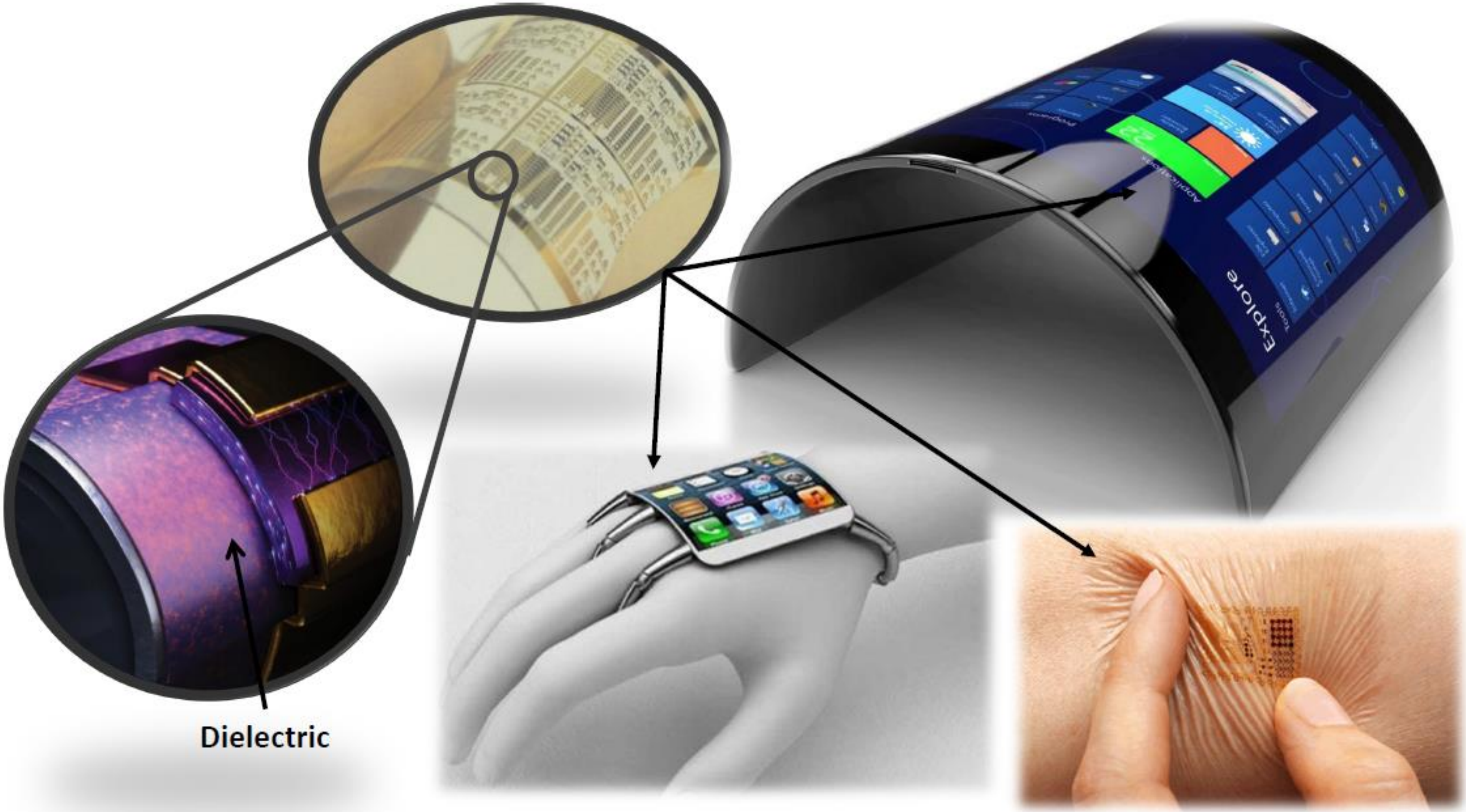
1. Introduction

Motivation



- ✓ The dielectric is a key component that determines the performance of flexible electronics

1. Introduction

Motivation

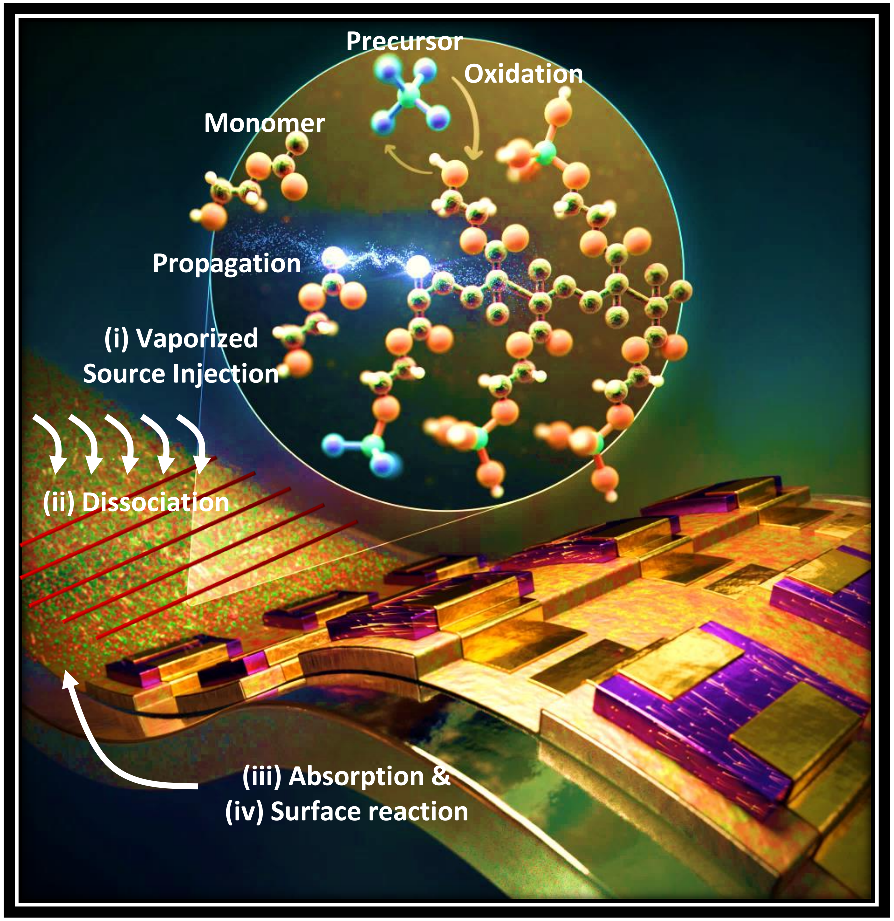
- Need to develop flexible high-k dielectric materials
- Demand for the use of a new process, called initiated chemical vapor deposition (iCVD)

- Karen K. Gleason (MIT) who is Mother of iCVD process
- Prof. Im adapt iCVD process into Korea (2010)

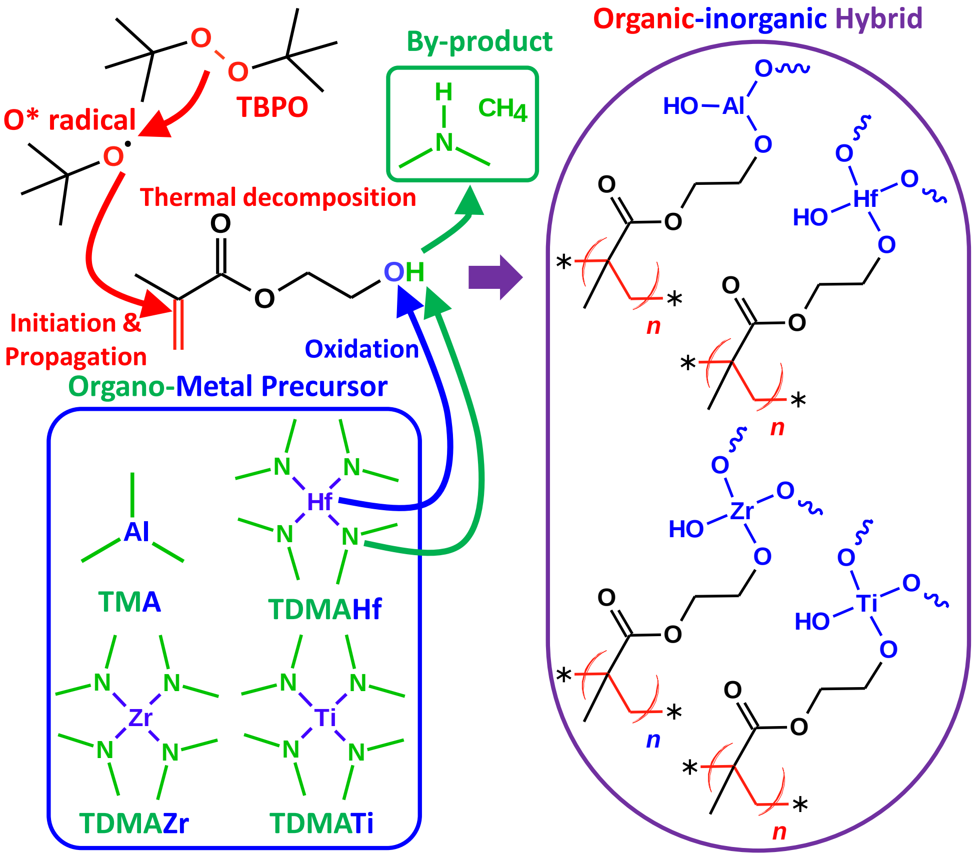
✓ The dielectric is a key component that determines the performance of flexible electronics

2. New Process (initiated Chemical Vapor Deposition; iCVD)

Process Scheme



Synthesis Mechanism



- ✓ Synthesis of AlO$_x$, HfO$_x$, ZrO$_x$, and TiO$_x$ contained hybrid dielectrics with systematical comparison
- ✓ The oxidation reaction between the hydroxyl (-OH) functionalities in the monomers and precursors
  → Formation of metal-oxide moieties in the polymer matrix

ACS Applied Materials & Interfaces, 2018, 10(43), 37326-34334 (Journal Cover)
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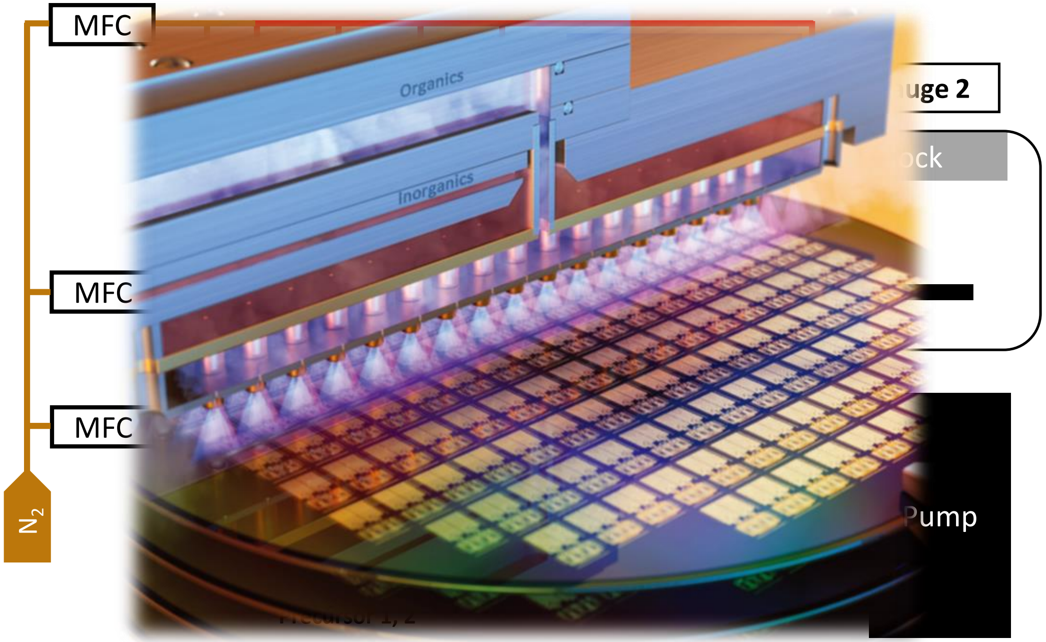
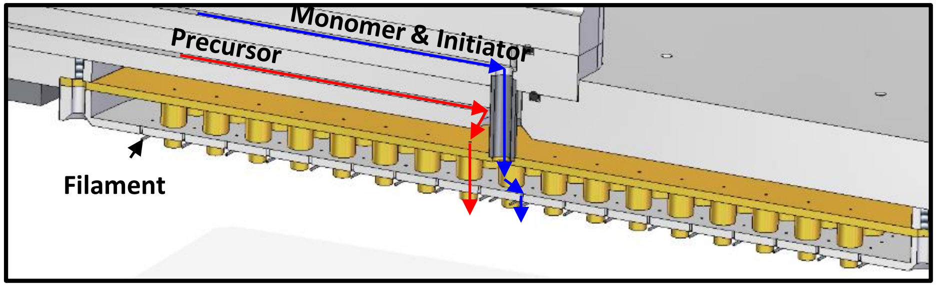
2. New Chamber

New Geometry of iCVD Chamber

Geometry of New Chamber

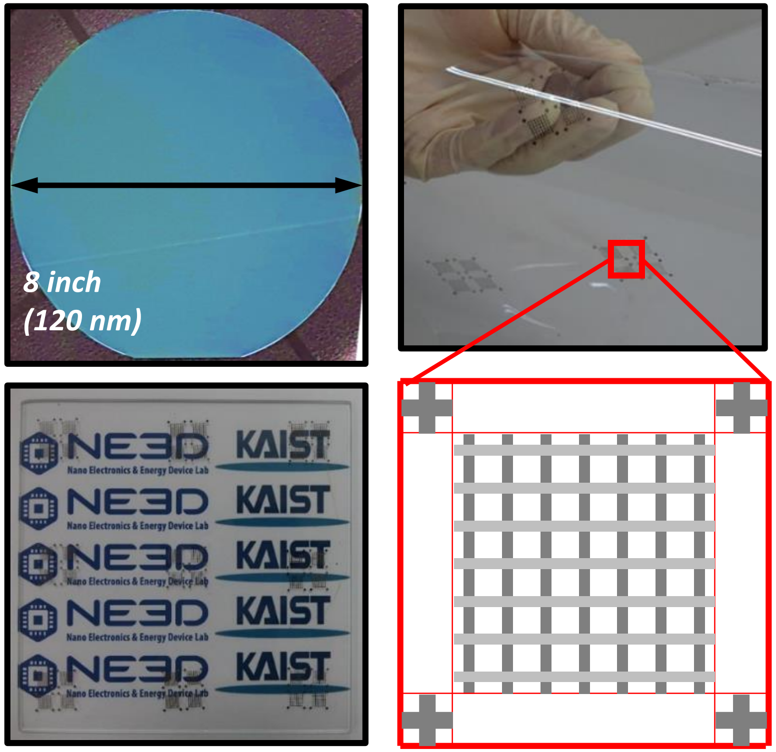


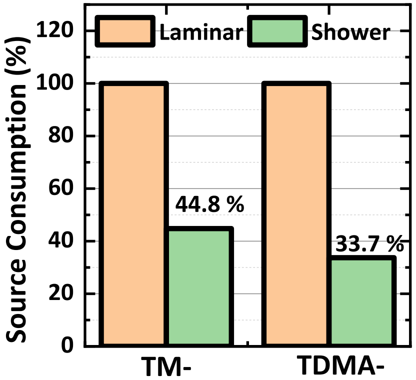


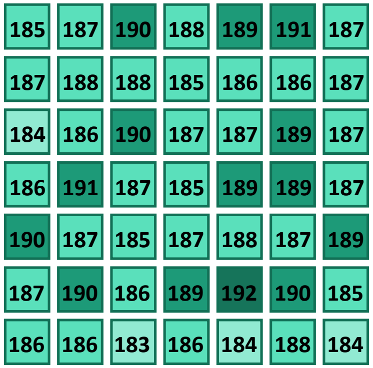
✓ New geometry design of iCVD chamber for large-area, uniform, conformal, homogeneous deposition of hybrids

- Dual shower-head structure module
- Evenly divide and spread vaporized sources
- Prevent non-surface reaction between sources
- Covering entire 8-inches

Large-Area Scale Deposition







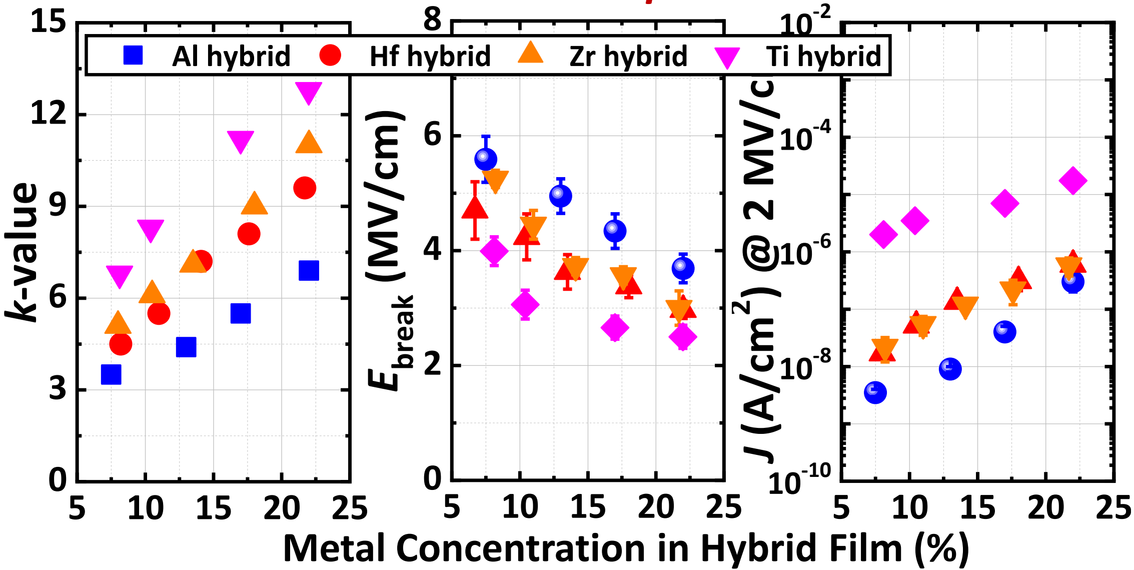
185	187	190	188	189	191	187
187	188	188	185	186	186	187
184	186	190	187	187	189	187
186	191	187	185	189	189	187
190	187	185	187	188	187	189
187	190	186	189	192	190	185
186	186	183	186	184	188	184

Macromolecular Materials & Engineering, 306 (3), 2000608, 2021, (Journal Cover)

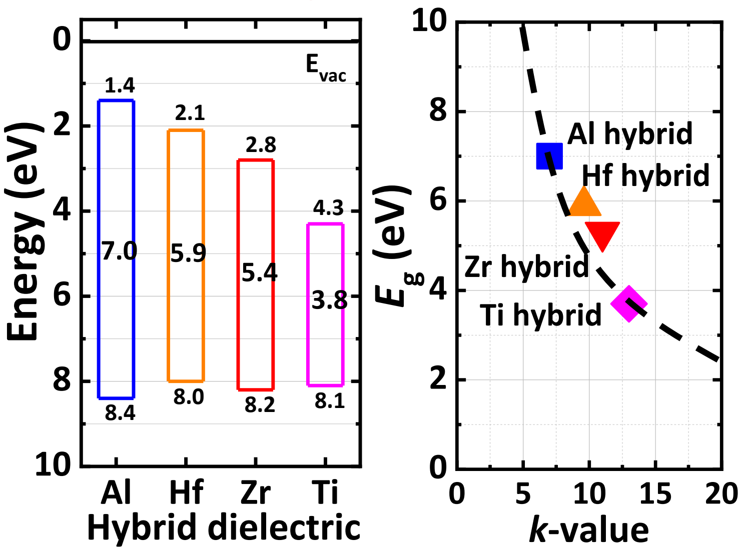
2. High-k Hybrids

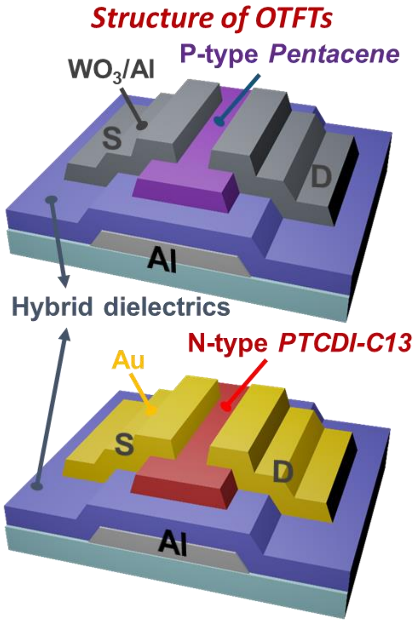
Electrical Properties

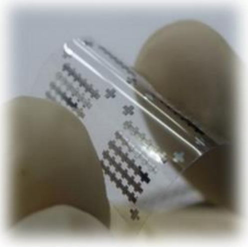
Dielectric Properties

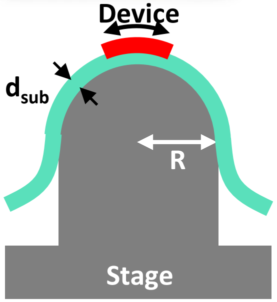


Energy Band Gap

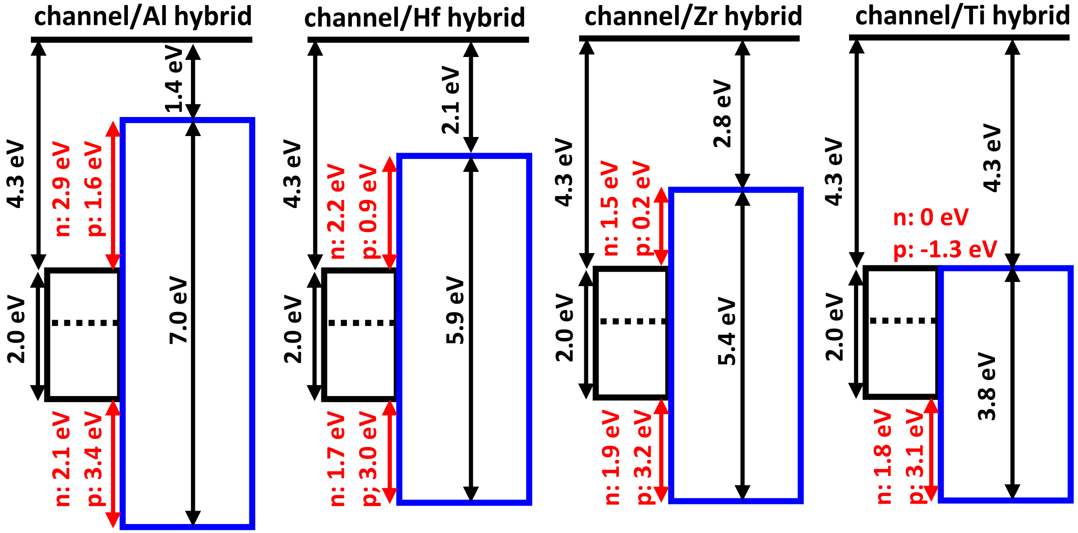








Energy Band Structure



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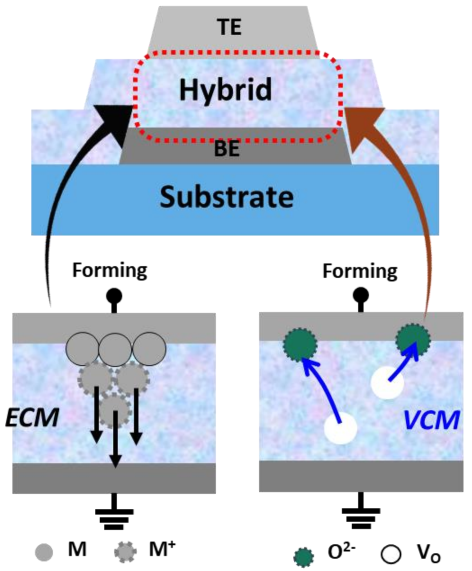
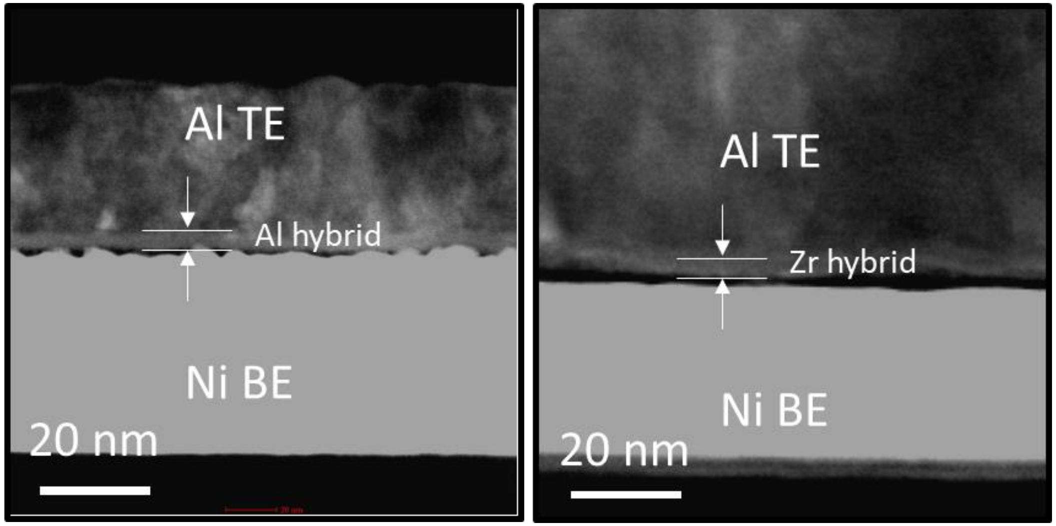
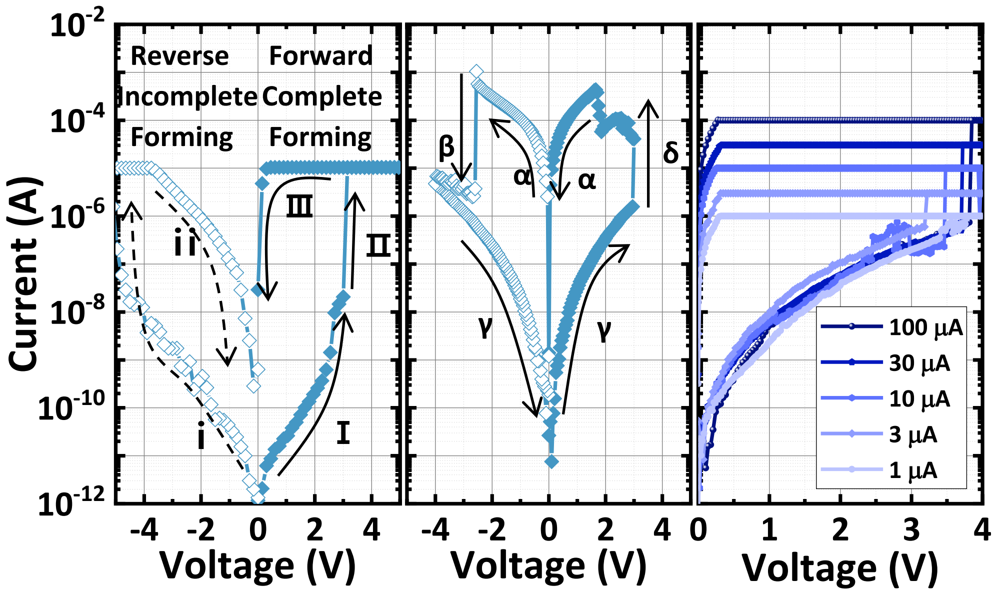
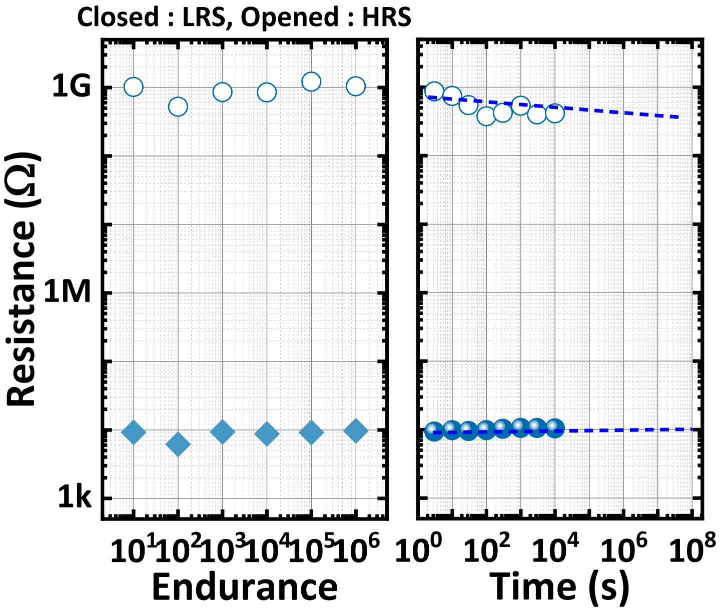
Proposal of ReRAM with Hybrids

Resistive Switching Behavior of Hybrid-based ReRAM

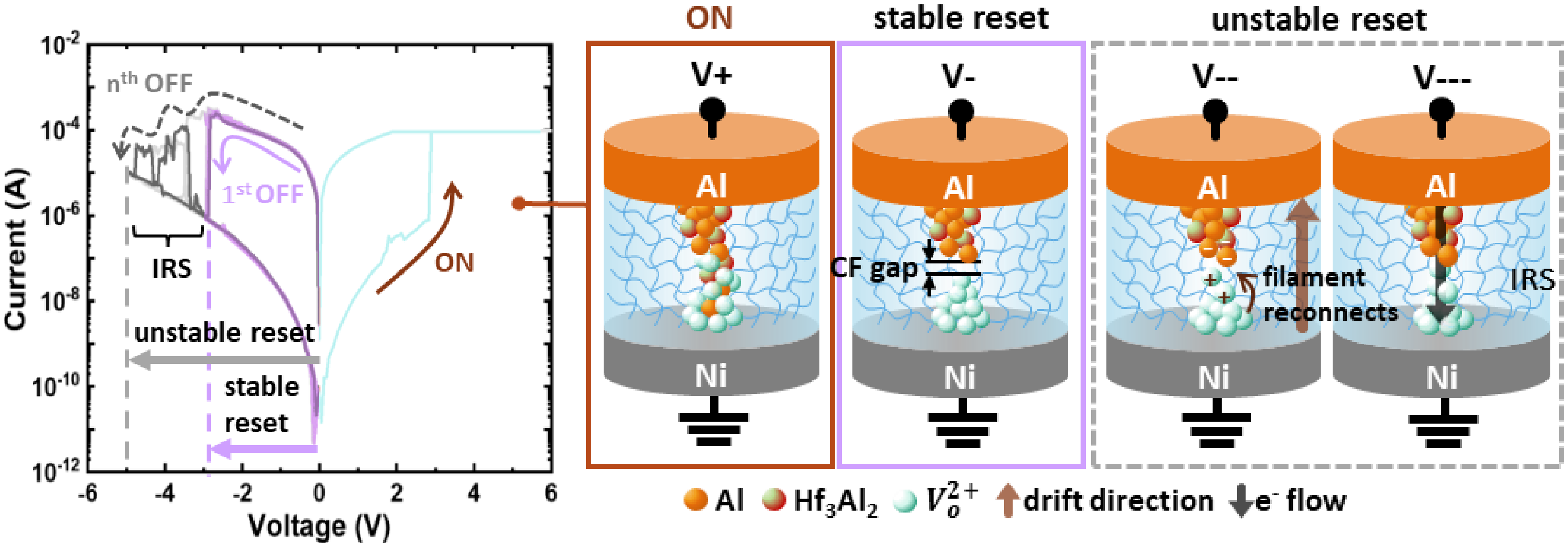


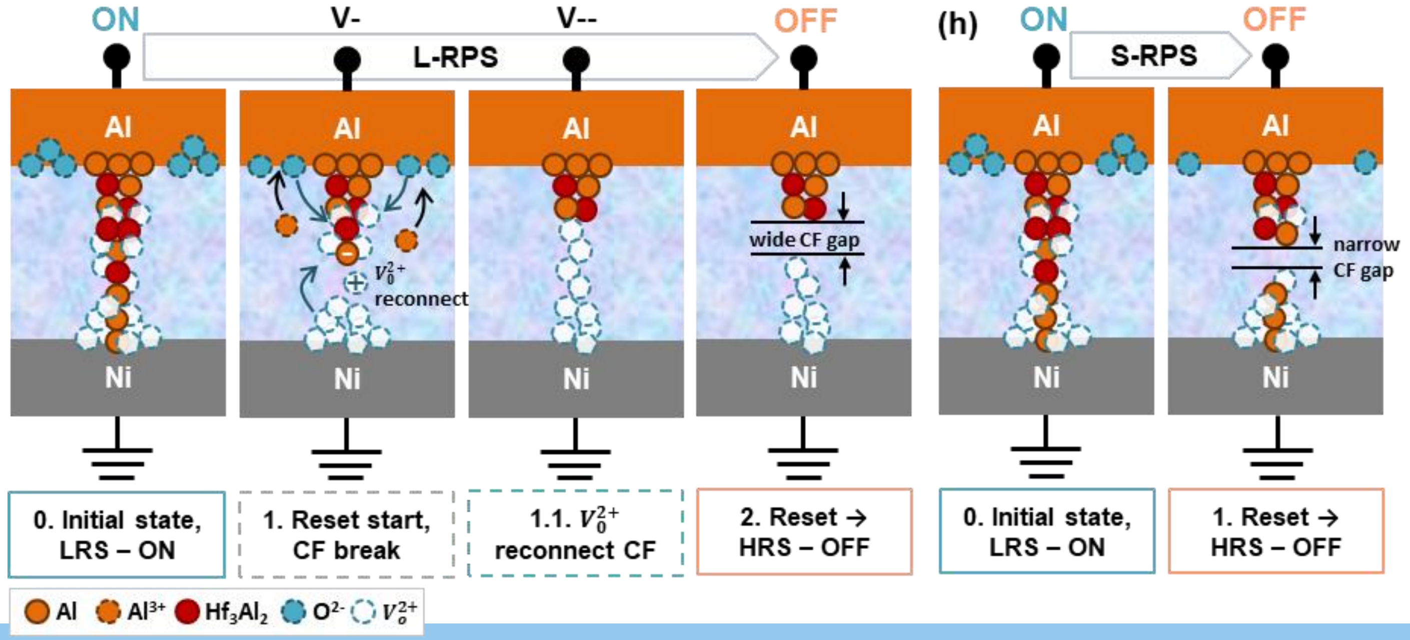






Conducting Filament Modeling in Hybrid

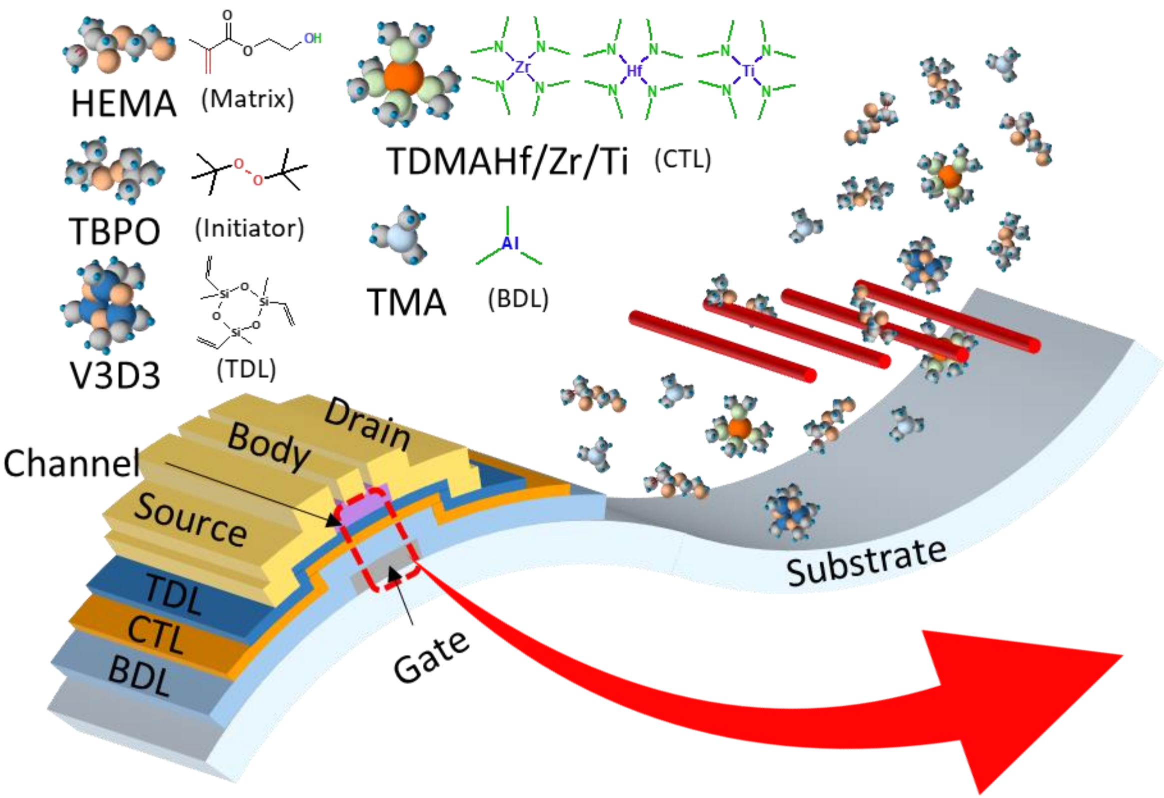


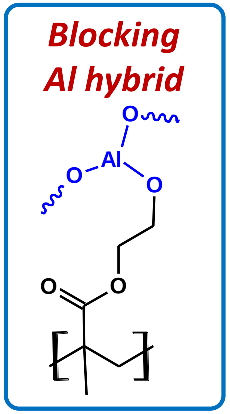


4. Charge Trapping Memory

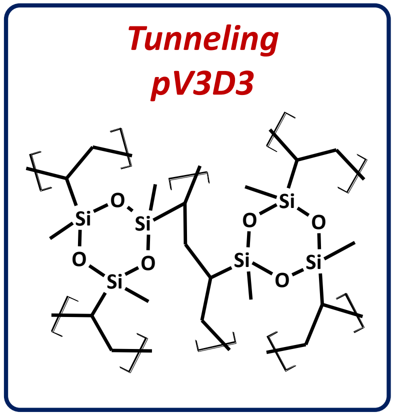
Proposal of New CT-Hybrid-ONVM

Synthesis Schematic and Device Structure

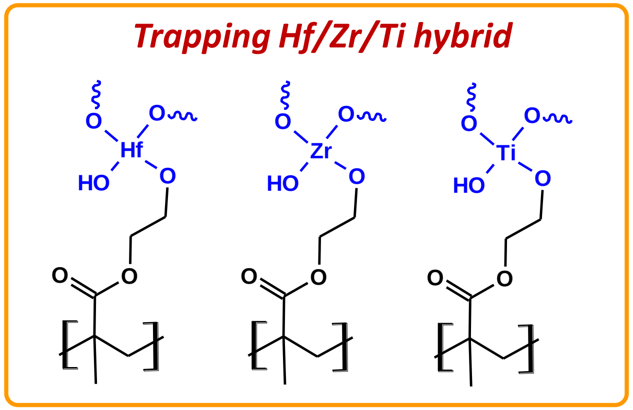




Blocking Al hybrid



Tunneling pV3D3



Trapping Hf/Zr/Ti hybrid

- ✓ Bottom-gated OTFT-based CT-ONVM device
  - → Blocking dielectric layer (BDL) : Al hybrid (Wide E_g, high-k=5.0)
  - → Charge trapping layer 1 (CTL1) : Hf hybrid (Narrow E_g, high-k=7.5)
  - → Charge trapping layer 2 (CTL2) : Zr hybrid (Narrow E_g, high-k=9.0)
  - → Charge trapping layer 3 (CTL3) : Ti hybrid (Narrow E_g, high-k=6.0)
  - → Tunnelling dielectric layer (TDL) : pV3D3 (Wide E_g, low-k=2.2)
  - → Channel : C13-PTCDI (n-type), pentacene (p-type)

- ➢ ***High Band offset***
- ➢ ***E-Field maximization in TDL***
- ➢ ***Charge trapping efficiency enhancement***

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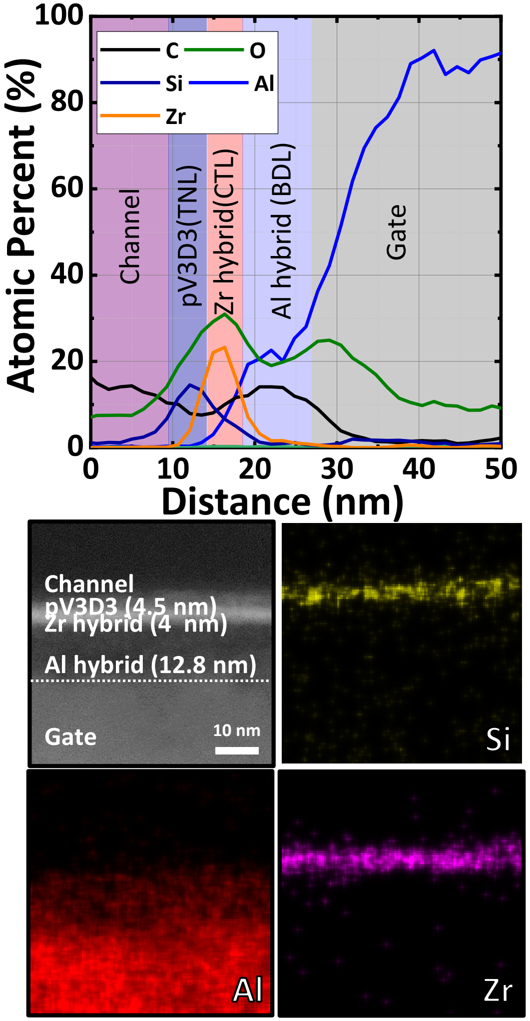
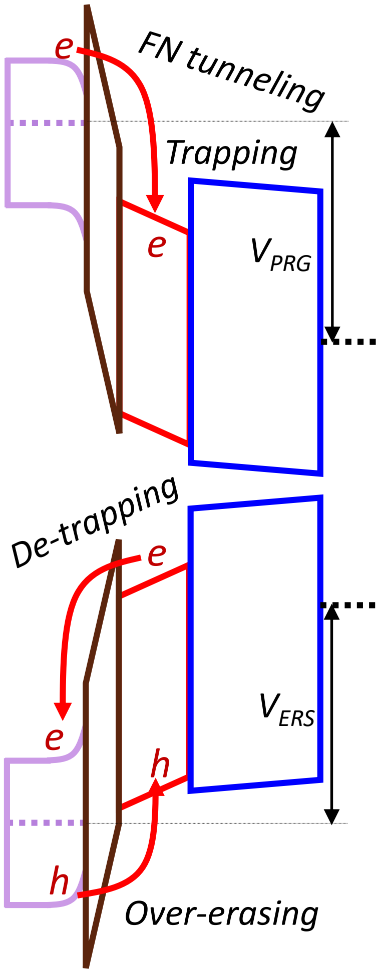
Program(PRG)/Erase(ERS) Behavior of CT-Hybrid-ONVM

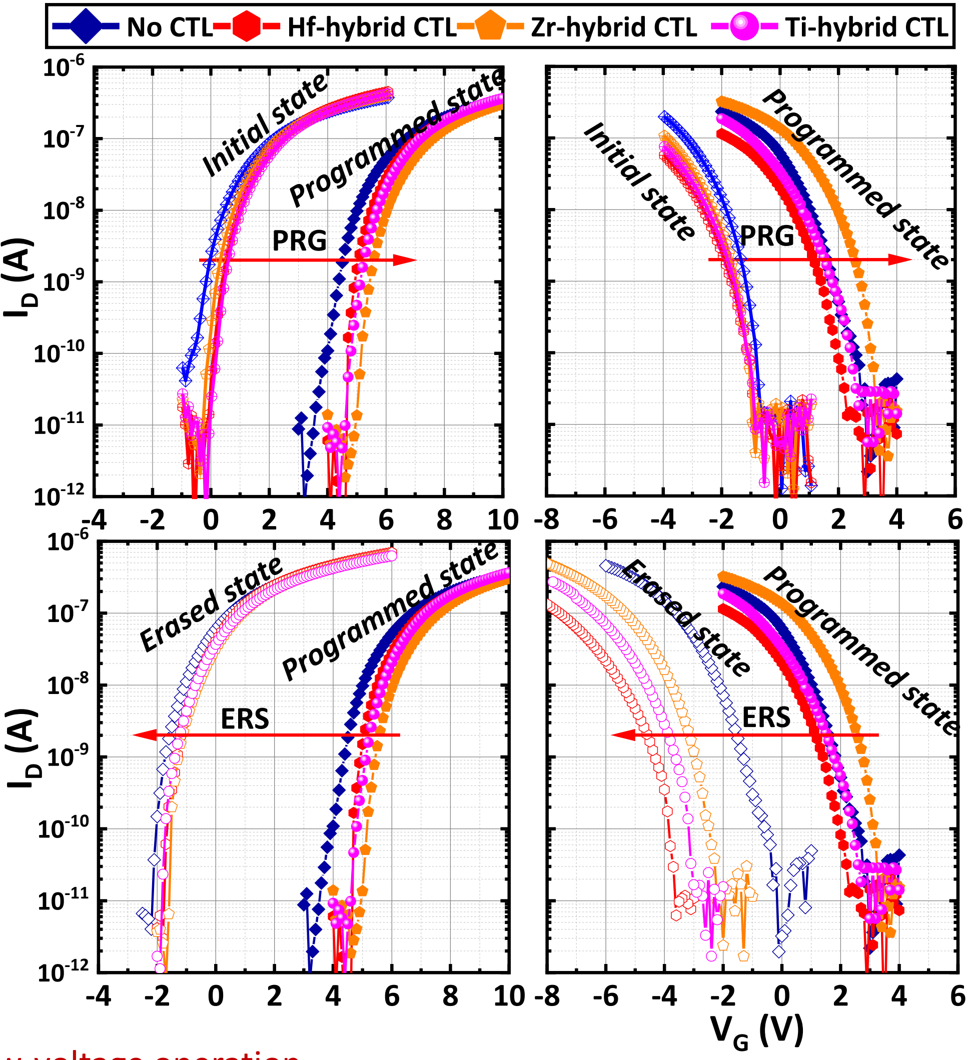
TEM + EDS Images



Energy Band Bending



Transfer Characteristic in PRG/ERS



- ✓ Ideal transfer characteristics with hysteresis free and low-voltage operation
  - → Advantageous in non-distorted Read operation
- ✓ Incremental step pulse programming/erasing (ISPP/ISPE), PRG/ERS speed, Endurance, and Retention

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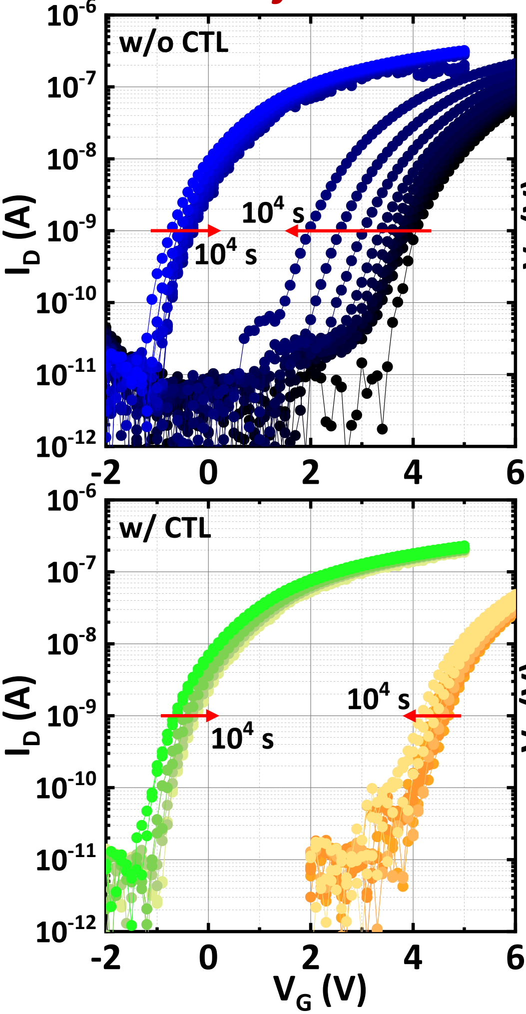
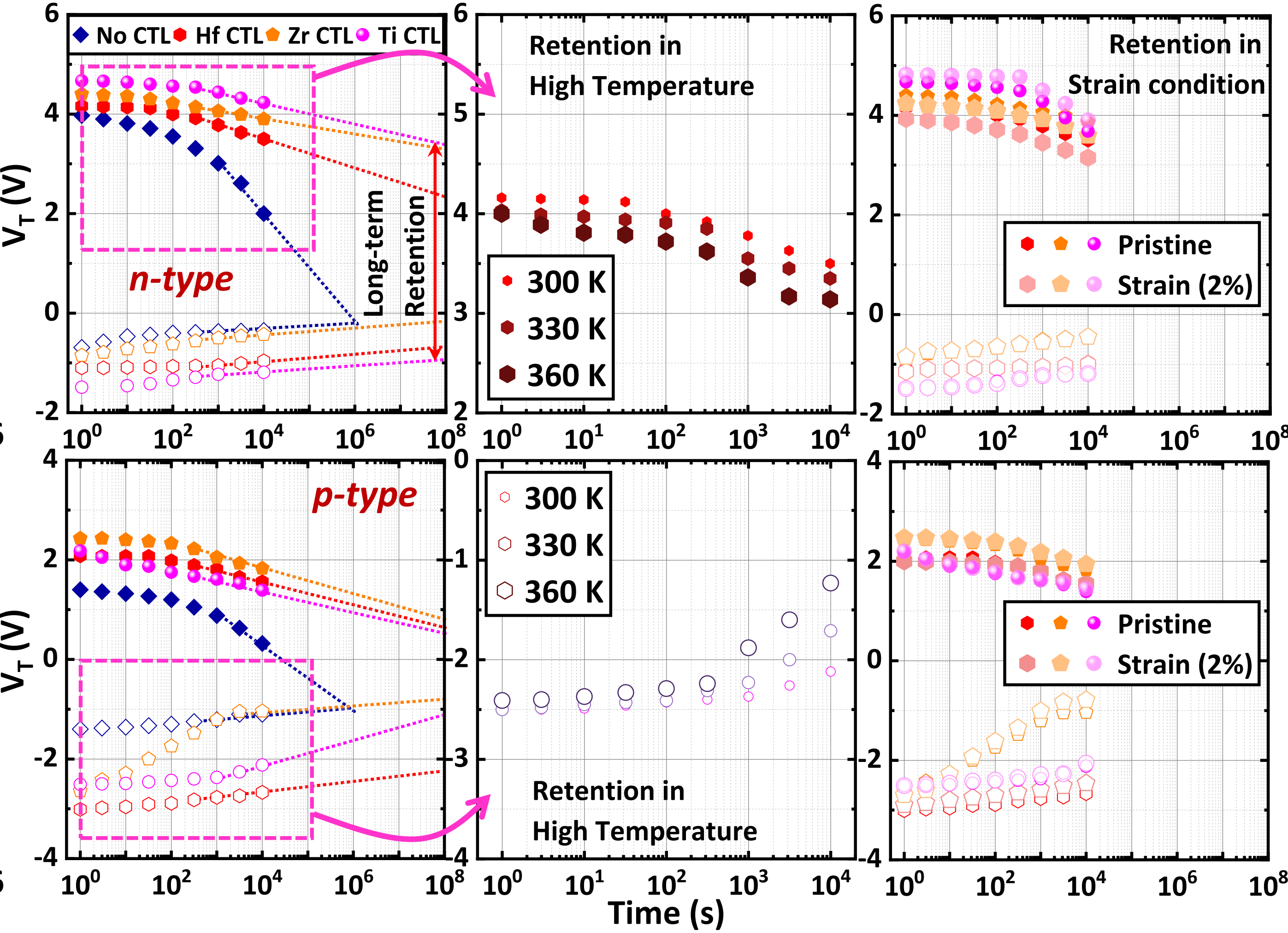
Retention Characteristics

Transfer curve



Retention Characteristics in Various Condition



- ✓ W/o CTL → Dramatic charge loss along with time, W/ CTL → Prevent charge loss to maintain V_T
- ✓ Retention properties in high temperature condition (for calculating trapping density in CTL; next page)
  - → Deep electron potential well, Shallow hole potential well
- ✓ No difference in retention between the pristine and the strained condition

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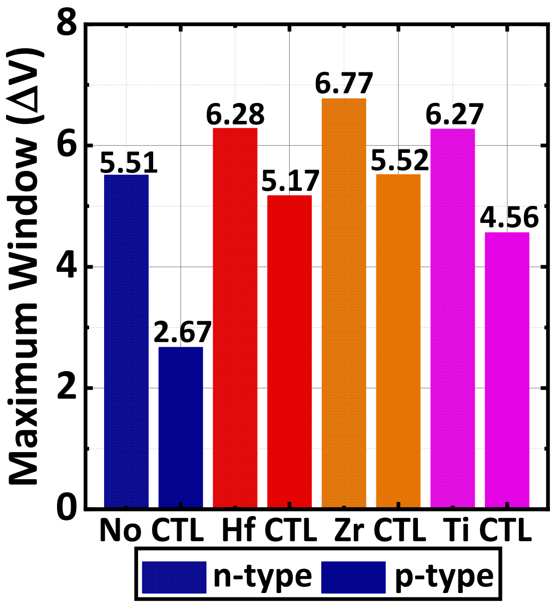
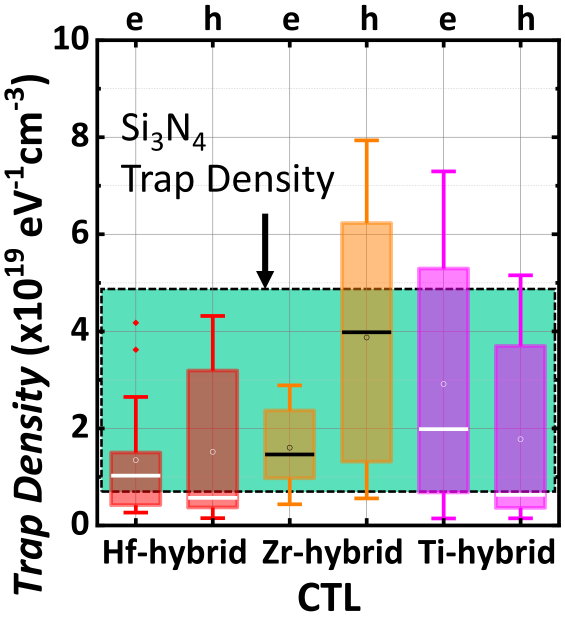
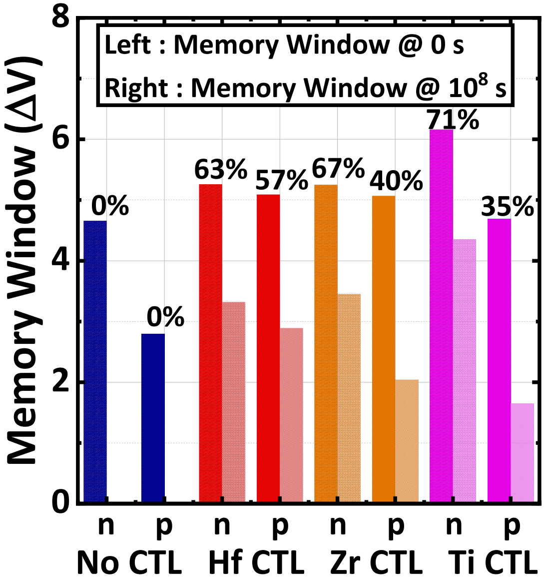
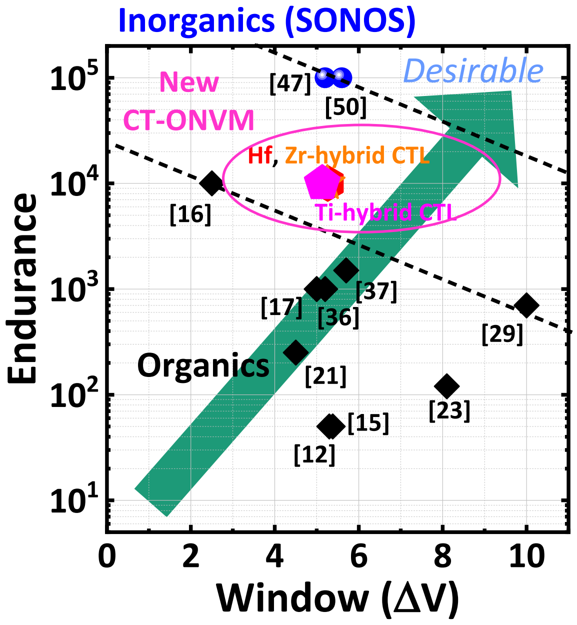
4. Charge Trapping Memory

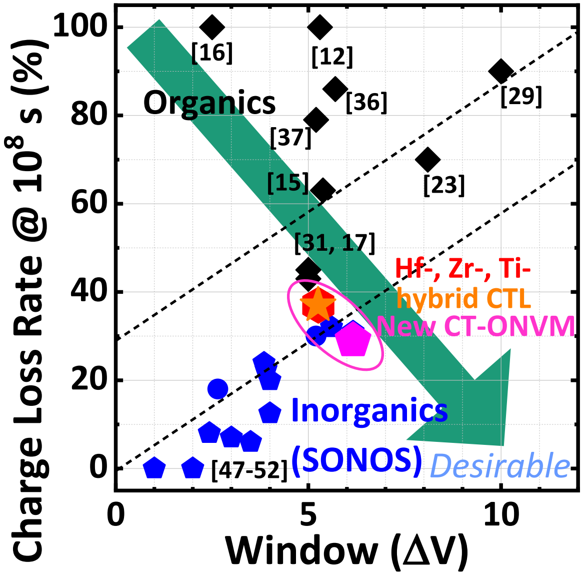
Benchmarks











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Thank You for Attention !