Bias stress instability of MoTe$_2$ FETs under DC and pulse mode stress

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### Graphene
- 2D material
  - Graphene is 2D material,
  - High mobility and unique characteristic but band-gapless

Transition Metal Dichalcogenides (e.g., MoS$_2$, MoSe$_2$, MoTe$_2$, WSe$_2$)

### TMDC
- Structure
  - TMDC, MX$_2$ structure
    - ($M$ is transition metal, $X$ is chalcogen)
  - $\sim$1.2eV bandgap

### MoTe$_2$
- Application
  - High on/off ratio, mobility and low consume power
  - Thin, flexible..
  - High performance FETs and memory

- Reliability issue important.
- MoTe$_2$ is less studied than MoS$_2$
Fabrication process

- Organic residue
- PDMS
- MoTe₂

20 nm SiO₂
n++ Si

Exfoliation & Transfer

H₂/ Ar mixture

Thermal annealing
200°C 30 minute
400/400 sccm(Ar/ H₂)

Photolithography (10 sec)

PR residue

Au evaporation

Lift-off

Cleaning

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Bias instability by DC mode

**NBTS**
- $V_{th}$ negative direction shift, bias stress increases, $\Delta V_{th}$ larger

**PBTS**
- $V_{th}$ positive direction shift, bias stress increases, $\Delta V_{th}$ larger

**Shallow trap**
- Shallow trap $E_i$
- Deep trap $E_v$

**Stretched exponential equation**
- $\Delta V_{TH} = \Delta V_{th0} \left[1 - \exp\left\{-(t/\tau)^\beta\right\}\right]
- \Delta V_{th0} : \Delta V_{th}$ at infinite time
- $\tau$ : trapping time of carriers
- $\beta$ : the stretched exponential exponent

- Under same bias stress, effective stress time increases, $\Delta V_{th}$ larger
- **PBTS tends to be the same as NBTS**, difference in the size of $\Delta V_{th}$
Bias instability by pulse mode

Duty cycle

- Duty cycle increases, $\Delta V_{th}$ larger
- DC mode $\Delta V_{th}$ is larger than pulse mode

Reproducibility

- In two device, duty cycle decreases
  same $\Delta V_{th}$ smaller

NBTS

- Under pulse mode NBTS,
  duty cycle increases, $\Delta V_{th}$ larger

PBTS

- PBTS tends to be the same as NBTS,
  difference in the size of $\Delta V_{th}$

DC vs Pulse

Shallow trap

Deep trap

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In order to study the reliability of MoTe$_2$, I studied the reliability of bias.

Result, $V_{th}$ changes depending on bias polarity in DC mode stress. In pulse mode stress, $V_{th}$ changes regardless of the bias polarity.

That is, the MoTe$_2$ device has a reliability issue.

In the future, I plan to study reliability based on temperature.
Thank you