Reversible and Non-volatile Magneto-ionic effect in W-CoFeB-MgO-HfO_2 ultra-thin films with Perpendicular Anisotropy

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INTRODUCTION

Background:
Spintronics enables the development of fast and non-volatile MRAM using current-induced switching through spin-transfer torque (STT) and spin-orbit torque (SOT).

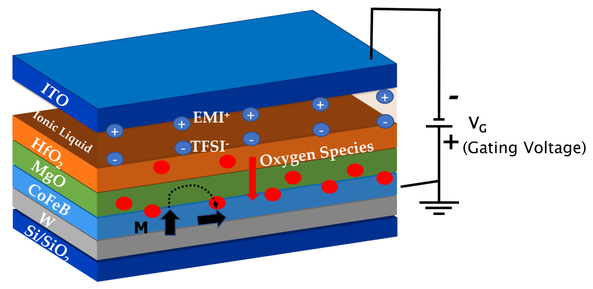
Challenges:
Critical switching current density remain large, and reducing the switching energy is crucial.

Potential solution:
Voltage controlled magnetic anisotropy (VCMA) effect
- Lower the switching energy
- Retain high anisotropy for thermal stability

Goal: Boosting magneto-ionic effect in CoFeB-MgO structures
- Compare amorphous and crystalline samples
- Use ion implantation/irradiation to enhance ion mobility and reversibility under E-field

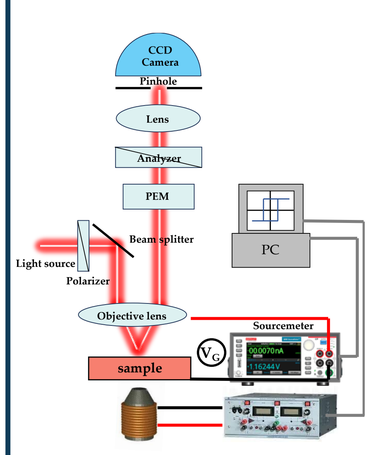
E-field Gating with Ionic liquid

$Si/SiO_2/W/CoFeB/MgO/HfO_2$/Ionic Liquid/ITO

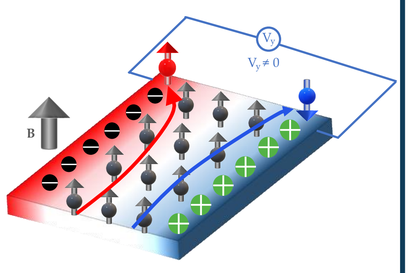


METHODOLOGY

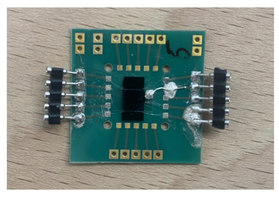
In-situ MOKE



Anomalous Hall effect

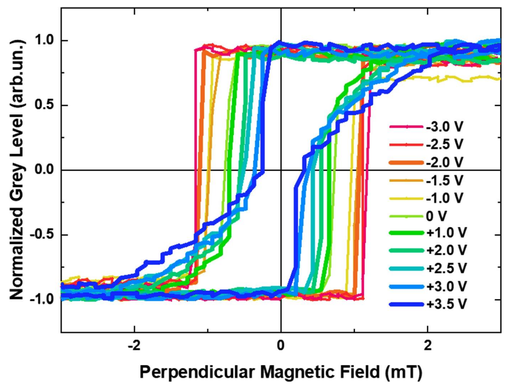


Sample holder

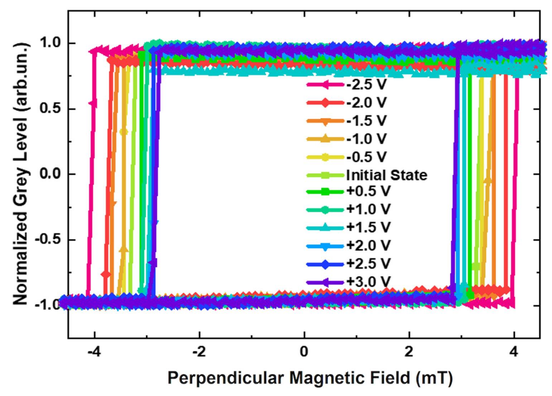


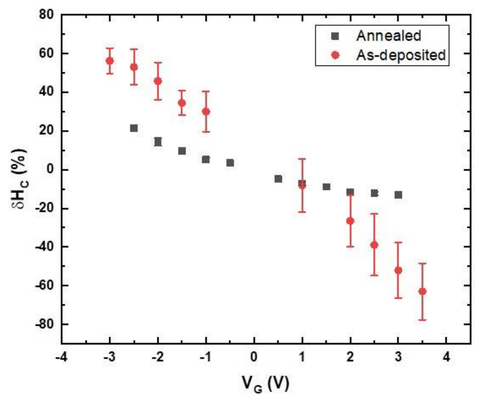
Charge-meditated ME effect in as-deposited and annealed system

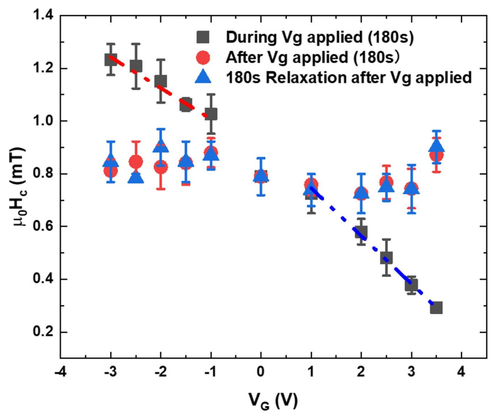
As-deposited

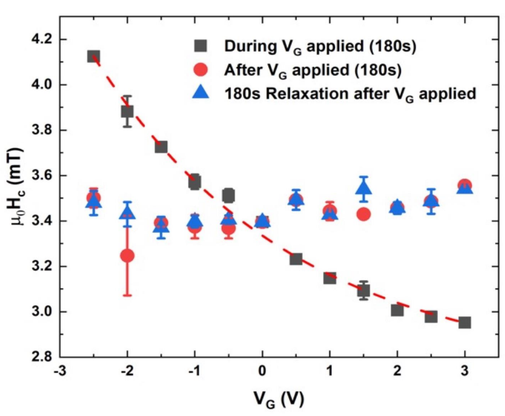


Annealed



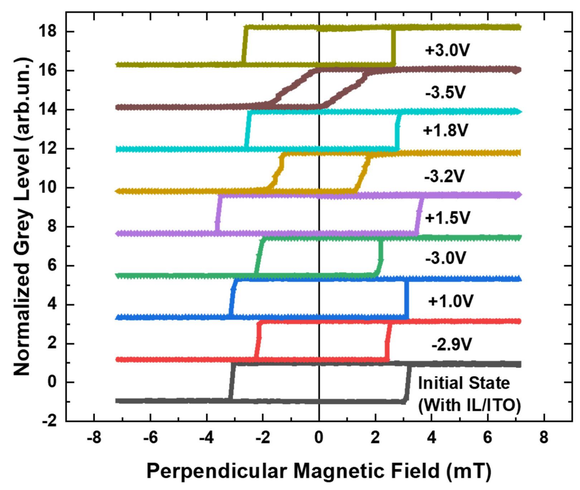


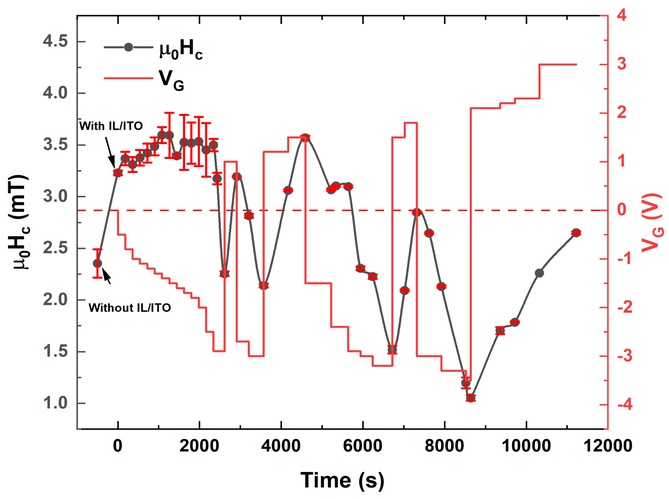




- Present in both as-deposited and annealed systems
- Spin-dependent charge accumulation
- Volatile but reversible effect
- As-deposited shows a more significant change with respect to zero-field state

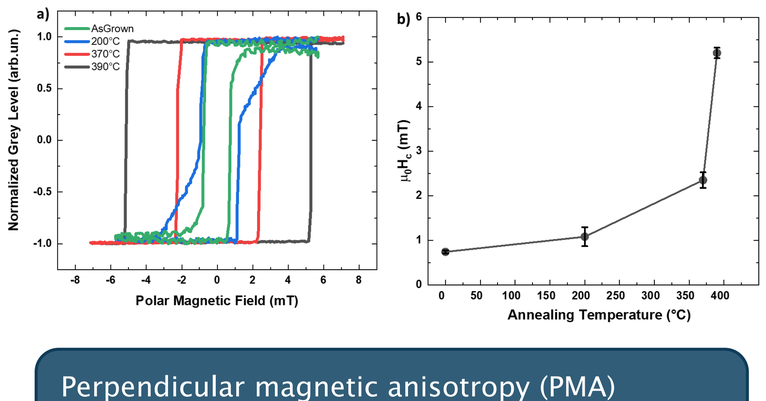
Magneto-ionic effect in the annealed system





- Oxygen ion migration
- Non-volatile
- Full reversibility
- Present only in the annealed system
- Consistent with the presence of grains boundaries

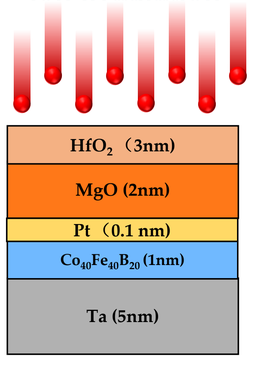
Annealing induced crystallization



Perpendicular magnetic anisotropy (PMA) enhancement
- Crystallization of W and CoFeB
- Enhancement of MgO/CoFeB interfacial state

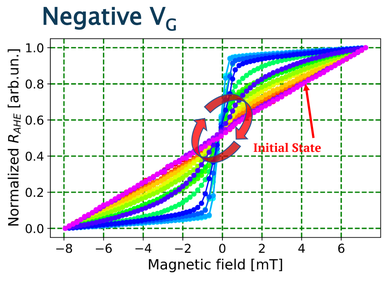
Boosting magneto-ionic effect by Ion Irradiation

Ion Irradiation

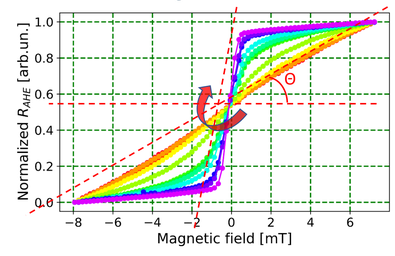


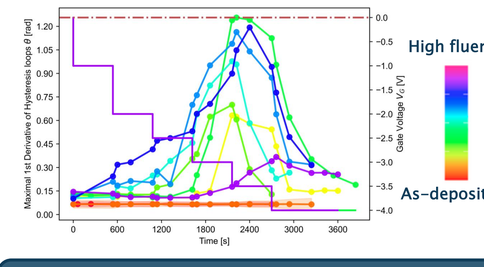
- Ions with energies from 1 to 30 KeV
- Electron Cyclotron Resonance (ECR) Ion Source
- Ultra-compact/small foot-print
- >1 inch coupon sample capability

Negative V_G



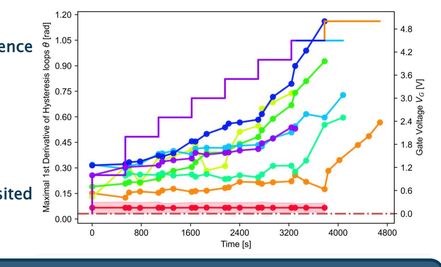
Positive V_G





High fluence

As-deposited



Significant magneto-ionic response induced by ion irradiation under selective conditions

Magneto-ionic effect in W-CoFeB-MgO-HfO_2 films with PMA can be enhanced using (i) crystallized samples and (ii) ion irradiation

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