Paper on Antiferromagnets

For the rising scientists in the fields of magnetic and electronic materials for data storage and transfer
Fairly technical tone, but not overly detailed on the many topics here

Figure showing efficiency trends over years

Brief, maybe mention uncertainty principle, tunneling, issues with scaling down (see conclusion too)

This is why we need to look at new possibilities. Maybe include brief descriptions of other solutions to avoid being too biased.

1

INTRO

- Current state of data storage/transfer
  - Traditional transistors, electronics, transfer of charge
- Moore's law, limitations
- Applications of magnetic materials, magnetic bits in hard drives
- Antiferromagnetic (AF) differ from ferromagnetic (FM), net zero magnetization
  - Take advantage of spintronics
  - Similar to electronics, but cares about spin rather than charge

Gives idea of how magnetic materials are useful to begin with, store data in magnetic ordering, not electrical field, charge or transport

Figure

I need to decide how much detail to give about quantum concepts. Should I assume knowledge of quantum origin of magnetism is known?

2

How have Antiferromagnets been used so far?

- Paired with ferromagnetic layers for pinning
  - Free layer switches
  - Called a spin valve
  - MRAM and HDD
- Useful beyond just pinning[1]
  1. **Fast dynamics**
  2. **Create no stray fields**
  3. **Resilient to outside fields**
- Uses are limited thus far, why?
  - Hard to write and read information

Any other examples? May need to dig

Example of spin valve in magnetic read heads MAGNETORESISTANCE

Figure

This discussion could come later

3

Fast Dynamics

- Higher resonant frequency than ferromagnets
  - Strong exchange interaction[2].
  - Faster switch, faster data
- Magnons: perturbations of spin in lattice
  - Faster propagation in AF than FM
  - Degeneracy in spin wave modes for AF, more states to carry data[3]
- Switching is difficult to achieve
  - Can't switch to outside fields like ferromagnet
  - Use strategies like pinning and SOT to switch

Connection! Maybe make reference

Figure

4

Create no stray fields

- Due to net zero magnetization, no stray fields
  - Meaning no magnetic field created outside the material
  - Won't perturb surroundings
- Replace ferromagnetic bits[4]
  - Pack magnetic bits more tightly
  - Do not perturb one another
  - No erasing data

Figure

Can explain later, weak ferromagnetism from canting can give stray field

5

Resilient to outside fields

- Magnetic order not easily changed
  - Data won't be erase/changed unintentionally
  - But makes hard to switch
- Spin orbit torque[5]
- Weak stimuli such as MOKE, spin hall effect, AMR
  - These CAN work, but weak, may not be practical for industry applications **(reference maybe?)**
- Interface coupling with ferromagnet[6]
  - But then stray fields could be issue from FM
- Maybe have weak ferromagnetism intentionally
  - Caused by canting spins
  - But now we have weak stray field

May want to trim out some stuff

Papers on this?

Discussion around this, why it is permissible

6

Summary/Conclusion

- Becoming more difficult to make things smaller
  - Tunneling, uncertainty principle
  - Costs, technology limitations (photolithography)
- Antiferromagnets represent lots of untapped potential
  - Gaining more attention, we need it to continue pushing forward the possibilities
  - Fast dynamics, Resilient to fields
- Currently being tested for MRAM applications
  - Used as bits, read out spin states with currents
  - FIND OTHER CUTTING EGDE TRENDS

Emphasize

1. https://doi.org/10.1016/j.fmre.2022.03.016
2. doi: 10.1038/srep35077
3. https://doi.org/10.1038/s41524-021-00570-0
4. https://arxiv.org/ftp/arxiv/papers/1611/1611.07027.pdf
5. https://beach.mit.edu/antiferromagnetic-spintronics/
6. https://doi.org/10.48550/arXiv.1509.05296