Effect of Inversion Asymmetry on Quantum Confinement of Dirac Semimetal Cd_3As_2

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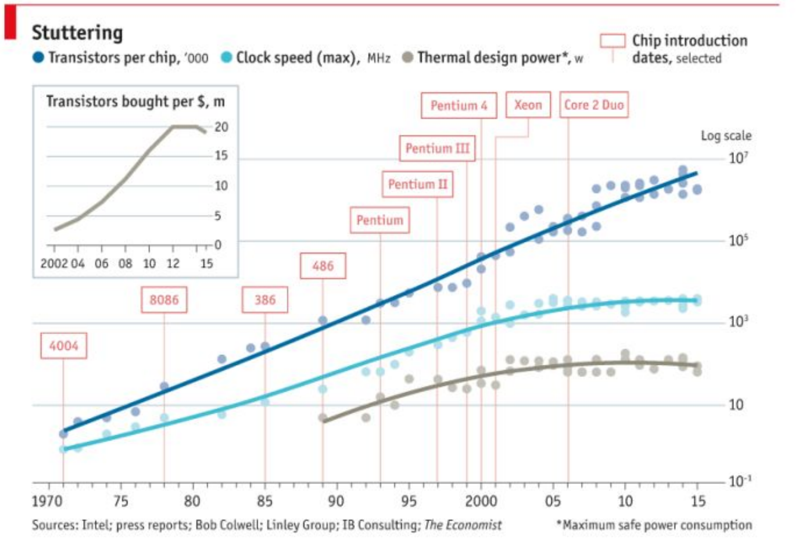
Motivation for Dirac Semimetals

- End of Moore's Law
- Current transistors are limited in efficiency, high power consumption
- Economically challenging to decrease sizes of transistors

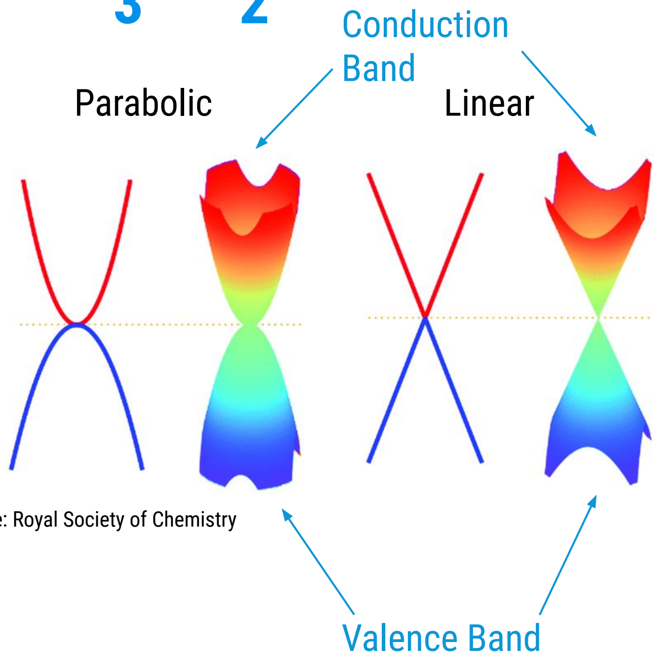


Promising Properties of Cd_3As_2

Linear band dispersion

Electron mobility 80x greater than Silicon (Nakazawa, 2018)

Backscattering Suppression



Source: Royal Society of Chemistry

Previous Studies on Cd_3As_2

- Exhibits 3D topological insulator state when quantum confined
- Hybridization affected by thickness of thin film
- Inversion asymmetry affected by environment disorder

Source: Orlando Sentinel

Research Goals

Quantum Simulation

We utilized the Python package Kwant to simulate electronic transport under quantum confinement

Formulating Applications

We propose novel topological devices utilizing Cd_3As_2 by manipulating inversion symmetry/hybridization terms

Explaining Interactions

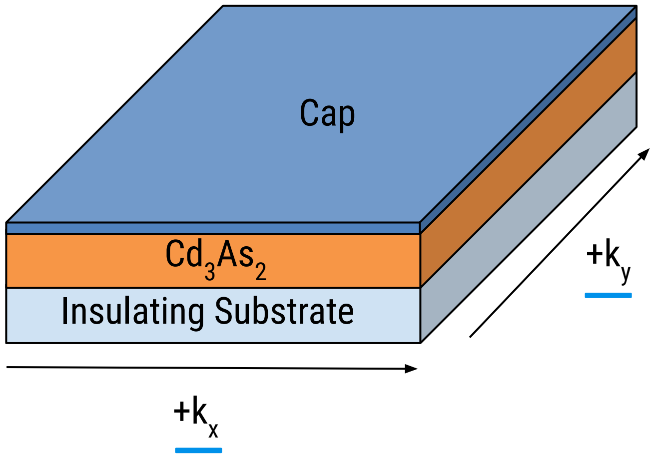
After simulating quantum transport and analyzing previous experimental data, we explain electronic interactions

Procedure

System Model — Quantum Simulation — Analysis

Δ_i related to E_{Top} - E_{Bottom}

Δ_h related to film thickness



$$\mathcal{H} = \hbar v_f (k_x \sigma_y - k_y \sigma_x) \otimes \tau_z + \Delta_i \mathbf{1} \otimes \tau_z + \Delta_h \mathbf{1} \otimes \tau_x + g^* \mu_B B_0 \sigma_z \otimes \mathbf{1}$$

Procedure

System Model

Quantum Simulation

Analysis

Quantum transport simulation with Kwant

$\Delta i > 0$
$\Delta h > 0$

$\Delta i > 0$
$\Delta h = 0$

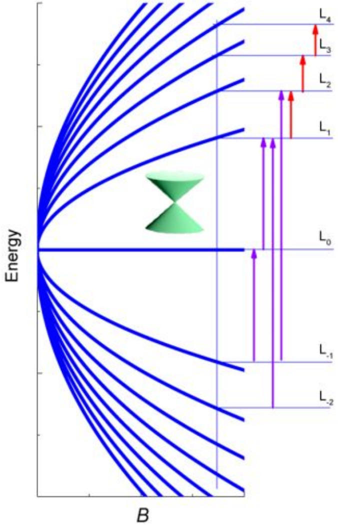
Analyze changes in band structure and electronic transport

Procedure

System Model

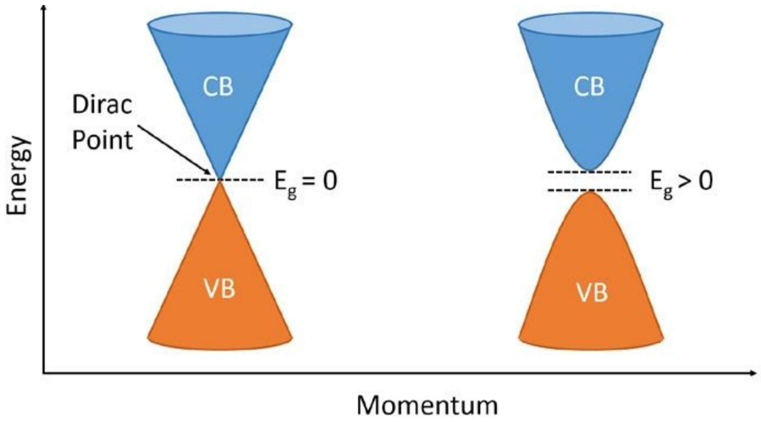
Quantum Simulation

Analysis



Source: Yuan et al.

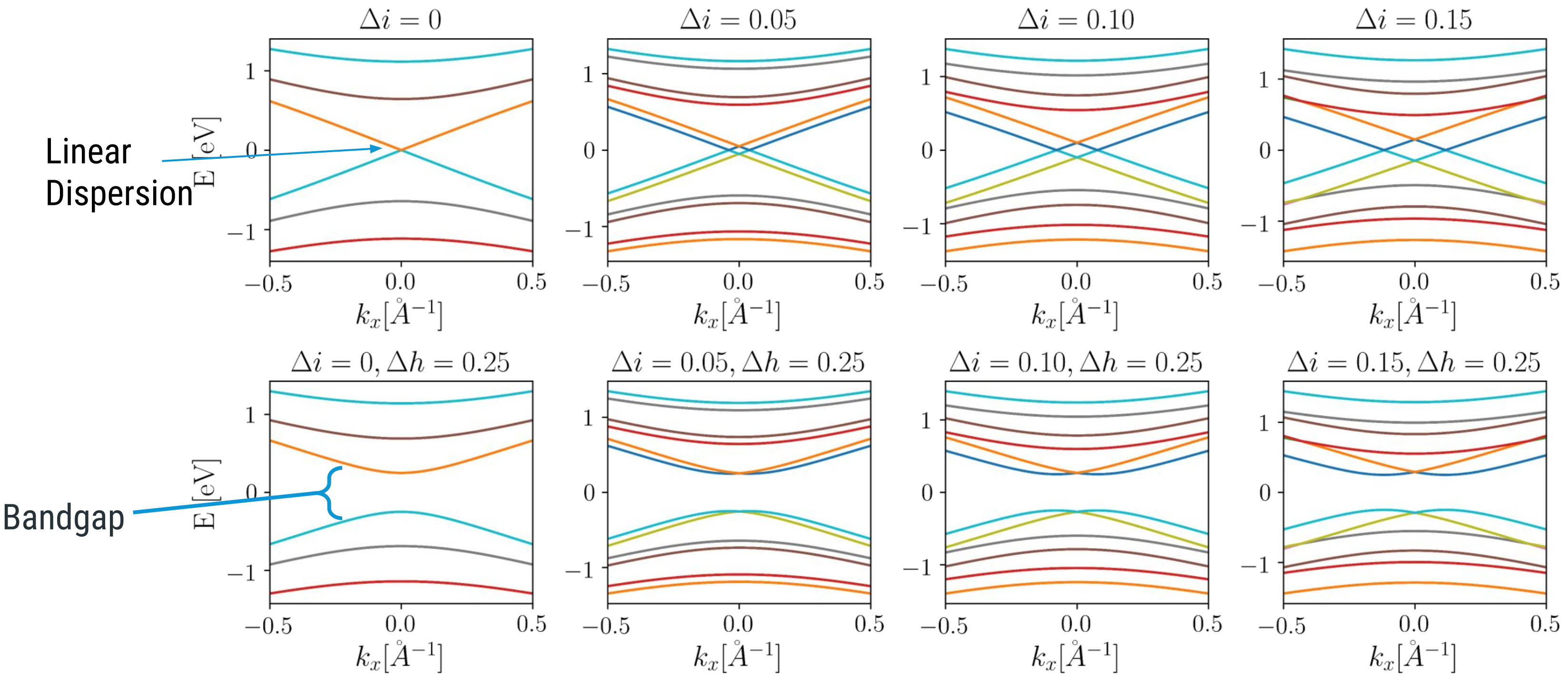
Landau Level Index Diagram



Source: Azo Materials

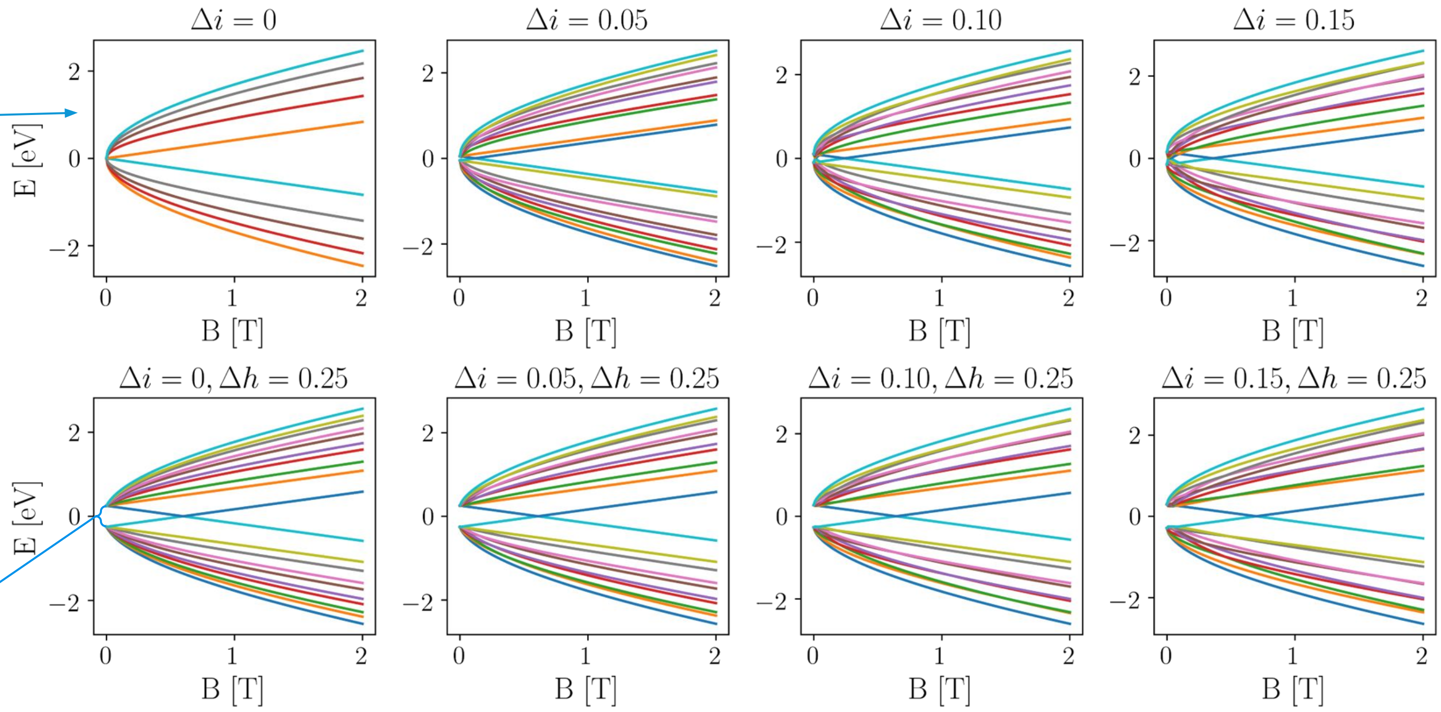
Energy-Momentum Dispersion

Energy - Momentum Dispersion



Energy vs. Magnetic Field

E ∝ √B

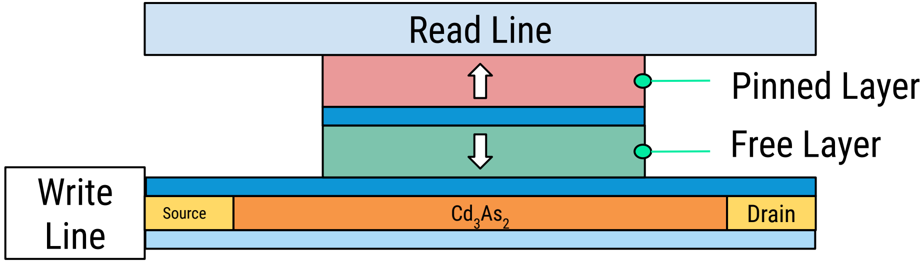


Bandgap

Spintronics

- Spin-polarized states through breaking of inversion symmetry
- Controllable Spin signals with electric field

SOT MRAM



Conclusion

Summary:

- Analyzed effects of inversion asymmetry and hybridization through quantum simulation
- Spin-polarized surface states develop when breaking inversion symmetry, promising for spintronics

Future Work:

- Testing for detection of spin-polarized states on Cd_3As_2
- Topological devices by manipulating spin-states of electrons

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