Vertical Heterostructures for Transistors, Photodetectors, and Photovoltaic Devices

Tech ID: 23667 / UC Case 2013-363-0

SUMMARY

The Duan group at UCLA has developed a high current density vertical field-effect transistor (VFET) that benefits from the strengths of the incorporated layered materials yet addresses the band gap problem found in current graphene technologies.

FULL DESCRIPTION

Since its isolation and increased production in 2003, graphene has been exploited for its remarkable strength, stability, and electron motility. The material has been used to improve a number of technologies including electronics, energy storage devices, and composites. Given the high conductivity of its ultra-thin sheets, it has potential to significantly reduce semiconductor size and improve power requirements. But despite the material's exceptional qualities, graphene does not naturally have a band gap, and therefore cannot be switched off. Future use of graphene in semiconductor devices will require a mechanism that increases the on/off current ratio.

UCLA researchers Drs. Xiangfeng Duan and Woojong Yu have developed a new technology that addresses the band gap problem of graphene. Their vertical field-effect transistor (VFET), which is an integration of vertically stacked multi-heterostructures of layered materials such as graphene, molybdenum disulfide (MoS2), and cobaltites (Bi2Sr2Co2O8), enables high current density by vertical current flow through overall semiconductor area with a large on/off current ratio. VFETs can deliver a current density 2-5 orders of magnitude and on/off ratios 1-2 orders of magnitude greater than existing graphene technologies.

SUGGESTED USES

- Lower cost, higher performance transistors, photodetectors, and solar cells
- Replace silicon in photovoltaic cells
- Can be used with silicon complimentary metal-oxide superconductor (CMOS) logic circuits for high integration into electronic devices
- Fabrication of more complicated device functions, such as a complementary inverter
- Usage as a vertical thin film transistor for flexible displays
- Storage of electrochemical energy

ADVANTAGES

- Delivers high current density
- 2-5 orders of magnitude greater than current technologies
- High on-off ratio
- 1-2 orders of magnitude better than typical graphene devices at room temperature
- Highly scalable
- Functions at room temperature

STATE OF DEVELOPMENT

- The method has been validated both by computer simulation and experimental testing
- Future plans include optimization of the graphene-semiconductor junction and graphene transfer technique

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INVENTORS

- Duan, Xiangfeng

OTHER INFORMATION

KEYWORDS

vertical-field, heterostructures, transistor, semiconductor, graphene, multilayered materials, cleantech

CATEGORIZED AS

- **Energy**
  - Solar
  - Storage/Battery
  - Transmission
- **Materials & Chemicals**
  - Composites
  - Electronics Packaging
  - Storage
  - Superconductors
  - Thin Films
- **Semiconductors**
  - Assembly and Packaging
  - Design and Fabrication
  - Materials
  - Other

RELATED CASES

2013-363-0

PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Issued Patent	9,685,559	06/20/2017	2013-363

RELATED MATERIALS

- Liu Y, Zhou H, Cheng R, Yu W, Huang Y, Duan X. Highly flexible electronics from scalable vertical thin film transistors. Nano Lett. 2014.
- Yu WJ, Liu Y, Zhou H, et al. Highly efficient gate-tunable photocurrent generation in vertical heterostructures of layered materials. Nat Nanotechnol. 2013.

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Approaching Schottky-Mott Limit in Van Der Waals Metal Semiconductor Contacts
- Ultrafine Nanowires As Highly Efficient Electrocatalysts
- Chemical Vapor Deposition Growth of the Large Single Crystalline Domains of Monolayer and Bilayer
- Double-Negative-Index Ceramic Aerogels For Thermal Superinsulation
- Single-Atom Tailoring of Platinum Nanocatalysts for High-Performance Multifunctional Electrocatalysis
- Palladium Alloy Hydride Nano Materials
- High Performance Thin Films from Solution Processible Two-Dimensional Nanoplates

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