**Docket #:** S15-116

# Energy-efficient phase change memory

This patented technology is a scalable, reliable non-volatile memory device that uses graphene as a thermal barrier to improve energy efficiency and reliability of phase change material (PCM). Conventional flash memory has had problems with reliability when scaled to the sub-20nm technology node. PCM memory is emerging as a new storage class memory and promising candidate to replace flash because it can deliver equal or better write bandwidth (in MB/s) by decreasing its programming current. This invention harnesses the electrical and thermal properties of graphene to confine heat inside the active PCM programming volume, reducing programming current and power, thereby increasing energy efficiency. The graphene also enhances PCM endurance and reliability by mitigating atomic migration from the PCM to an electrode. This technology could help pave the way for PCM to replace flash for fabricating small, low-power memory devices with high driving speeds and high integration.

**Stage of Research**
The inventors fabricated a graphene-PCM device and demonstrated ~40% lower RESET current compared to control devices without graphene while achieving high programming endurance (up to $10^5$ cycles), fast switching speed (sub-50 ns) and good on/off resistance ratio (between 30 and 100).

## Applications

- **Non-volatile memory devices** with end user applications in general types of electronic devices where the interplay between thermal and electrical effects plays a key role in device operations

## Advantages

- **Energy efficient** - thermal resistance of graphene reduces programming current and power
  - ~40% lower RESET current compared to control devices without graphene
  - reduces energy requirements to extend battery life
  - relieves burden of scaling efforts in PCM technology
- **Improved endurance** - graphene acts as a physical barrier to prevent heat from leaking out of the PCM which increases reliability

## Publications


- Ahn, C., Fong, S. W., Kim, Y., Lee, S., Sood, A., Neumann, C. M., ... & Wong, H. S. P. (2015). Energy-efficient phase-change memory with graphene as a thermal barrier. *Nano letters*, 15(10), 6809-6814.
- Graphene key to high-density, energy-efficient memory chips, Stanford engineers say *Stanford Report* Oct. 23, 2015.


## Patents

- Published Application: 20160276585
- Issued: 9,583,702 (USA)

## Innovators

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