Multi-state data storage leaving binary behind

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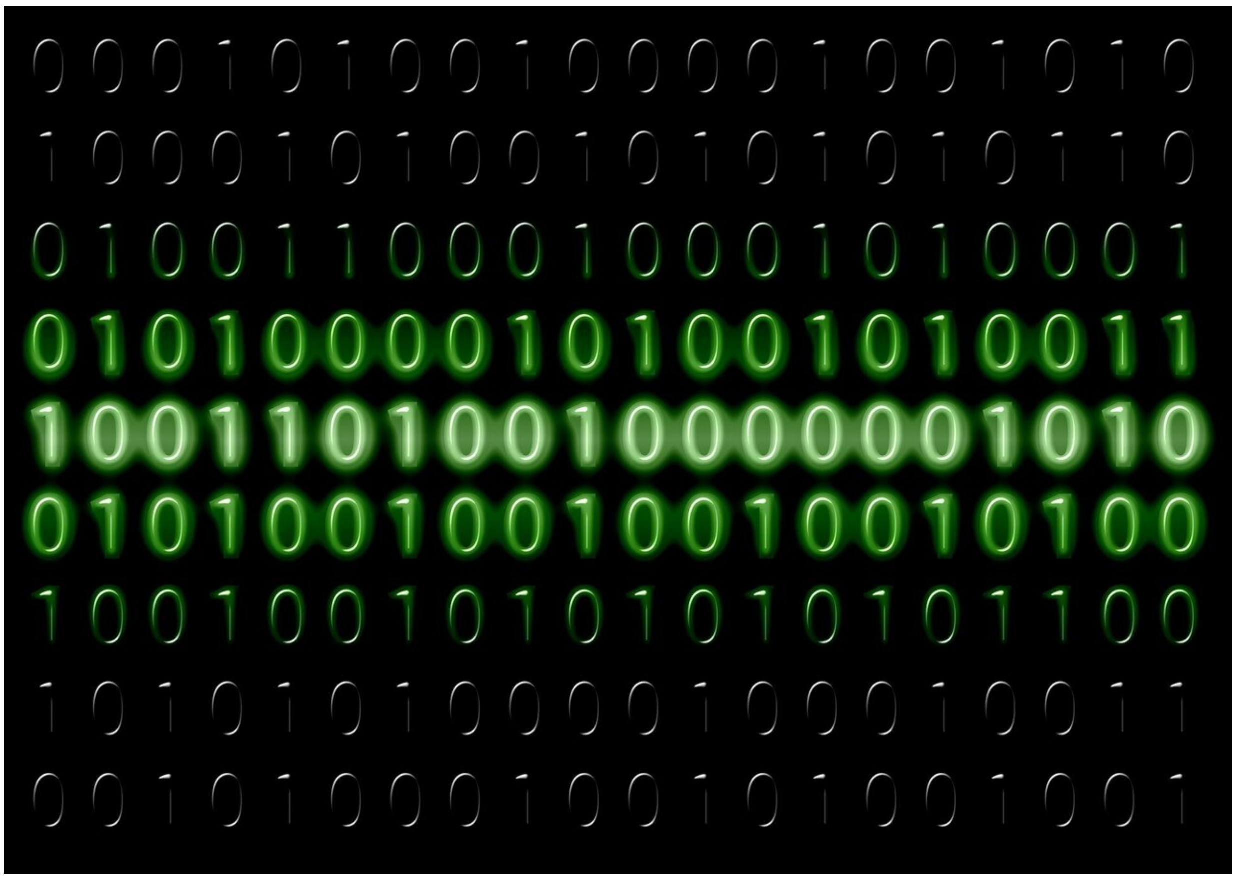

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The total amount of data stored in data centers around the globe is of the order of ten zettabytes (a zettabyte is a trillion gigabytes), and we estimate that amount doubles every couple of years.

With 8% of global electricity already being consumed in information and communication technology (ICT), low-energy data-storage is a key priority.

To date there is no clear winner in the race for next-generation memory that is non-volatile, has great endurance, highly energy efficient, low cost, high density, and allows fast access operation.

A joint international team comprehensively reviewed multi-state memory data storage, which steps beyond binary to store more data than just 0s and 1s.

Multi-state memory: more than just zeroes and ones

Multi-state memory is an extremely promising technology for future data storage, with the ability to store data in more than a single bit (i.e., zero or one) allowing much higher storage density (amount of data stored per unit area.

This circumvents the plateauing of benefits historically offered by Moore's Law, where component size halved abut every two years. In recent years, the long-predicted plateauing of Moore's Law has been observed, with charge leakage and spiraling research and fabrication costs putting the nail in the Moore's Law coffin.

Non-volatile, multi-state memory (NMSM) offers energy efficiency, high, nonvolatility, fast access, and low cost.

Storage density is dramatically enhanced without scaling down the dimensions of the memory cell, making memory devices more efficient and less expensive.

Neuromorphic computer mimicking the human brain

Multi-state memory also enables the proposed future technology neuromorphic computing, which would mirror the structure of the human brain. This radically-different, brain-inspired computing regime could potentially provide the economic impetus for adoption of a novel technology such as NMSM.

NMSMs allow analog calculation, which could be vital to intelligent, neuromorphic networks, as well as potentially helping us finally unravel the working mechanism of the human brain itself.

The paper reviews device architectures, working mechanisms, material innovation, challenges, and recent progress for leading NMSM candidates, including:

- Flash memory
- magnetic random-access memory (MRAM)
- resistive random-access memory (RRAM)
- ferroelectric random-access memory (FeRAM)
- phase-change memory (PCM)

Nonvolatile Multistates Memories for High-Density Data Storage was published in *ACS Applied Materials and Interfaces* in September 2020.

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