Quantum dot based flash memories: The Holy Grail, unifying DRAM and Flash?

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State-of-the-art solid-state memory technology is currently split into two classes: volatile memories (e.g. DRAM) and non-volatile ones (e.g. Flash). Volatile memories show fast data-access times, performing write and erase operations in tens of nsec, and are durable, allowing for over 10^{15} write/erase cycles, but are unable to store data for periods longer than a few msec. On the other hand, Flash memories guarantee a storage time of at least 10 years, but the write and erase operations take long (order of msec) and the voltages applied are high, physically damaging the devices, and thus heavily affecting their durability (circa 10^6 write/erase cycles).

We present here our recent breakthroughs in the development of QD-Flash,[1] a novel non-volatile memory device based on self-assembled quantum dots (QDs). QD-Flash takes advantage of the potentially huge localization of carriers in QDs to create what has been defined the "Holy Grail of computing",[2] i.e. a non-volatile memory device with the same fast data access time and durability as a DRAM.

QD-Flash achieved write times of 6 ns[3] and erase times of 350 ns.[1] Erase times as short as 10 ns have been predicted for an appropriate choice of the erase voltage.[4] The longest storage time for holes at room temperature (230 s) was obtained for $In_{0,5}Ga_{0,5}As$ QDs in GaP with an additional AlP barrier.[5]

In this work we give an overview of our work on QD-Flash and present our latest result: A storage time for holes at room temperature of 3.9 days, > 3 orders of magnitude larger than the previous record figure. This result is depicted along with all previous results and some theoretical predictions in Fig. 1. Since the storage time depends on the localization energy of the carriers in the QDs, it can be dramatically increased just by choosing yet not explored nano-heterostructures. Fig. 1 shows how material architecture brought about an improvement of 14 orders of magnitude in hole storage time at room temperature since the start of our work and proves that QD-Flash can achieve non-volatility: 10 y storage time.

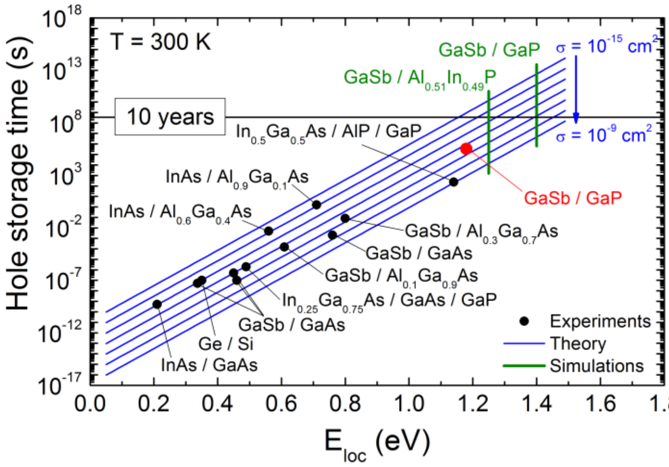

Figure 1: *Hole storage time measured at room temperature in different heterostructures (black dots) alongside the theoretical predictions for other materials (green lines). The results presented in this work are marked in red.*

References

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Dieter H. Bimberg, received the Diploma in physics and the Ph.D. degree from Goethe University, Frankfurt, in 1968 and 1971, respectively. From 1972 to 1979 he held a Principal Scientist position at the Max Planck-Institute for Solid State Research in Grenoble/France and Stuttgart. In 1979 he was appointed as Professor of Electrical Engineering, Technical University of Aachen.

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His research interests include the growth and physics of nanostructures and nanophotonic devices, ultrahigh speed and energy efficient photonic devices for future datacom systems, single/entangled photon emitters for quantum cryptography and ultimate nanomemories based on quantum dots.