

Probabilistic Bits for Unconventional Computing Systems

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Abstract:

The rapid development of artificial intelligence in the big data era has increased the demand for solving complex combinatorial optimization problems (COPs) such as vehicle routing problem (VRP), which are difficult to efficiently handle with conventional von-Neumann computing systems. Quantum computing, which utilizes quantum bits (qubits) based on the superposition of spin, shows potential for solving COPs. However, the requirement of cryogenic operating environments—necessary for noise elimination and accurate spin detection—remains a significant drawback. To address these challenges, probabilistic computing (P-computing) has recently been proposed as an alternative approach to emulate quantum supremacy even at room temperature.

Here, we showed probabilistic bits (P-bits) with a novel Ti/SiO_x/Ti stack, which is a fundamental building block for P-computing. The SiO_x layer typically exhibits reliable TS behavior, resulting in robust voltage oscillations. When a Ti scavenging layer was introduced at the interface, oxygen vacancies were provided to the SiO_x, causing oscillation to occur probabilistically. Through physical analysis and numerical calculations considering the charging and discharging process, we investigated the underlying mechanism of P-bit operation in the Ti/SiO_x/Ti stack. This results in a sigmoidal probability curve for ‘1’ over a wide range of input voltage. Finally, we verified that leveraging the developed SiO_x-based P-bit can significantly accelerate the algorithm for finding the optimal path in the vehicle routing problem through MATLAB simulation.