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Toward large-scale integration of silicon spin qubits with low variability

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Abstract

Silicon spin qubits hold promise for realizing large-scale integrated arrays, thanks to advancements in manufacturing technologies in silicon integrated circuits. Research on silicon qubits has historically focused on initial demonstrations using small-scale structures with a few quantum dots; however, since around 2018, structures for large-scale integration have been proposed, and manufacturing and demonstrations have started. At the same time, the importance of research in performance variability is rapidly recognized in preparation for large-scale qubit operations.
To suppress the performance variability, eventually, it will be necessary to identify its source and develop appropriate processes. However, even preliminary quantitative evaluation of variability is not straightforward. For instance, qubit devices typically consist of multi-gate structures to control potential wells and barriers. Therefore, electrostatic coupling among gates can complicate property evaluations for each gate stack. Additionally, proposing structures that are tolerant of manufacturing variations and minimize their impact on performance variation can also be beneficial.
Our research team at AIST works on device development and demonstrations aiming for future applications in large-scale arrays, focusing on the fin-shaped silicon spin qubit structure using a silicon-on-insulator (SOI) substrate. From the perspective of variation, we examine the impact of work function variation, as one instance to understand the effects of electrostatic coupling in multi-gates. Through this study, we propose a method to mitigate this impact while improving the accuracy of threshold-voltage evaluation in each gate stack. We are also exploring innovative substrate and micro-magnet structures to achieve qubits capable of

suppressing performance variation even under certain dimensional non-uniformity. We would like to present our recent research activities, including these topics, in the presentation.