Electronic Supplementary Information (ESI) for

In-situ TEM Observation of Void Formation and Migration in Phase Change Memory Devices with Confined Nanoscale $Ge_2Sb_2Te_5$

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Supplementary Figure

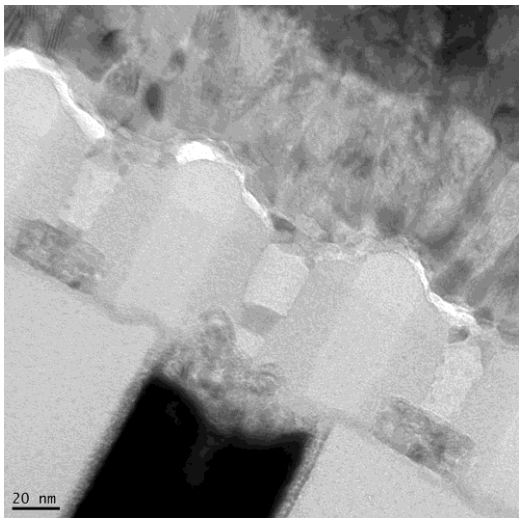

Figure S1. TEM image showing a TEM sample failed during SEM nano-probing test due to the volatilization of GST.

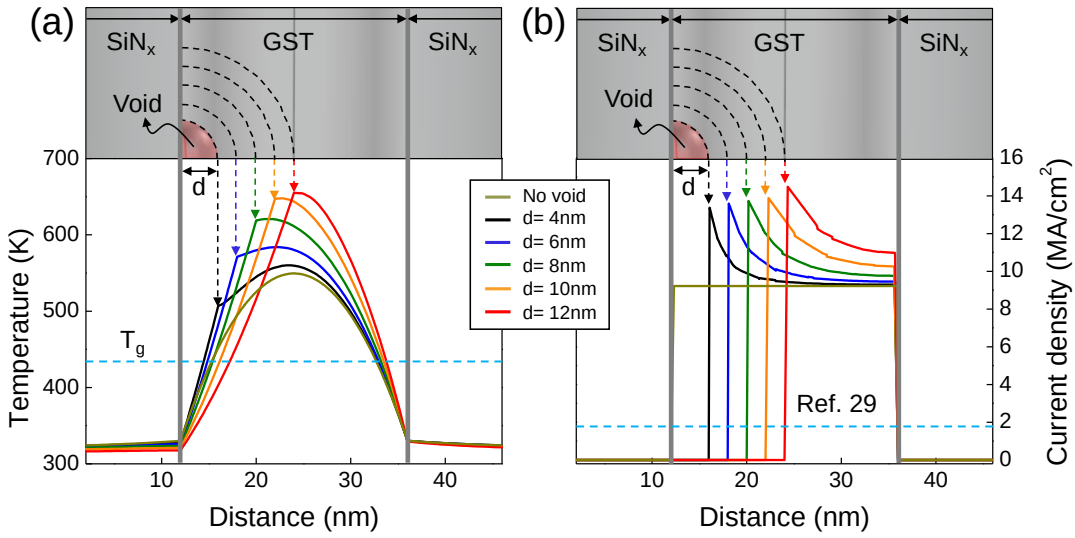

Figure S2. Finite element modeling of temperature distribution and current density. (a) Temperature profiles and (b) current density profiles across the confined GST nanopillar with different size of void. The glass transition temperature (T_g) and the critical current density for initiating the electromigration of GST elements is indicated by a blue dotted line (Ref. 29).

Movie legends

Movie S1. In-situ TEM movie showing the void nucleation and growth in a confined GST nanopillar PCRAM device during the passage of multiple set pulses. After the first set pulse being applied, a void is formed at the GST/SiNx interface (sidewall) near the TiN BE. During the following application of pulses, the void continue growing at the same location with changing contrast in TEM. The void is marked by black arrow. The original movie recorded at 25 fps is played two times faster (50 fps).

Movie S2. In-situ TEM movie showing the large voids (black arrows) formed by the coalescence of small nanoscale voids in the GST cell upon application of set voltage pulses. The original movie recorded at 25 fps is played four times faster (100 fps).

Movie S3. In-situ TEM movie showing the void migration toward the positively charged TE in a confined GST nanopillar PCRAM device by the application of multiple set pulses. During the migration of void the GST accompanies noticeable change of diffraction contrast induced by constant crystallization and crystal reorientation. The void is marked by black arrow. The original movie recorded at 25 fps is played four times faster (100 fps).

Movie S4. In-situ TEM movie showing the reset-stuck failure by void formation during cyclic reset and set testing. The two large voids (black arrows) show the contraction and expansion in response to the reset and set pulses, respectively. The original movie recorded at 25 fps is played in real-time.

Movie S5. In-situ TEM movie showing the reset-stuck failure by void formation. While the GST shows appearance and disappearance of the diffraction contrast and Moiré fringes by crystallization and amorphization by set and reset pulses, respectively, the large void formed on the bottom electrode is not removed but remained. The original movie recorded at 25 fps is played in real-time.