Large-area Memristive Crossbar Array for Biomedical Image Processing

Professor Shaibal Mukherjee
Indian Institute of Technology, Indore

There is a substantial demand for memristive devices and systems that demonstrte CMOS compatibility, stable and fast resistive switching speed, long endurance and retention time, three-dimensional (3D) integration capability for high-density information storage and in-memory computation. The 3D integration capability makes memristive crossbar arrays (MCAs) more capable to executive large-scale logic operations and brain-inspired computation. However, a critical challenge to design and fabricate 3D large-area scale MCA is the variability in the resistive switching parameters, which are the inherent properties of a memristive system.

Here, an illustration will be presented regarding gradual development of single-level robust memristor system based on transition metal oxides (TMOs) in the form of ZnO and Y2O3. The performance calibration along with analytically developed models will be briefly described. Subsequently, the electrical performance and stability analysis of a Y2O3-based MCA on a 3-inch Si (001) wafer will be discussed. Significantly low levels of device-to-device (D2D) variability in switching parameters such as VSET (2.64%) and VRESET (10.13%) and ultralow cycle-to-cycle (C2C) variability parameters in VSET (0.2%) and VRESET (1.07%) are observed from the developed MCA. Experimental probing to study the impacts of various input signal parameters such as applied voltage (VA), compliance current (ICC), and pulse width (PW) on the variability parameters is performed. The fabricated memristive devices in the crossbar array also show a minimum level (2%) of overall variations in the values of coefficient of variability (CV) both for VSET and VRESET for varied levels of compliance current, applied voltage and input pulse-width. Finally, a design strategy will be briefly discussed to deploy two-dimensional (2D) discrete wavelet transform (DWT) and tunable Q-wavelet transform (TQWT) based decomposition of chest X-ray images (CXIs), computed tomography (CT) scan, and magnetic resonance image (MRI) in which MCA is used for storage and data processing. The 2D TQWT has resulted promising values of peak signal-to-noise ratio (PSNR) and structural similarity index measure (SSIM) at the optimum values of its parameters. These images have been further used for the classification of COVID-19 and non-COVID-19 images using ResNet50 and AlexNet convolutional neural network (CNN) models. The average accuracy values achieved for the processed CXIs classification in small and large datasets are 98.82% and 94.64%, respectively, which are higher than the reported conventional methods based on complementary metal oxide semiconductor (CMOS) based techniques. The average accuracy of detection of COVID-19 via proposed method of image classification has also been achieved with less complexity, power, and area consumption along with lower cost estimation as compared to CMOS-based technology.

This MCA-based image processing is extremely promising to diagnose other diseases like influenza and tuberculosis, from X-rays, CT scans and other imaging techniques.

Research Initiative for Supra-Materials