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Physical Unclonable Functions with Silicon-Rich SiOx Dielectric Devices

Background

With the advent of the internet of things (IoT), internet security concerns have increased dramatically. All secure communications require random number generation to create a secure key. The naturally occurring randomness in semiconductor device characteristics can provide random numbers via appropriate reading circuitry from within an integrated circuit, with the generated number being unique to each individual circuit. This has been demonstrated with static random-access memory (SRAM) and resistive random-access memory (RRAM), and arrays of these memories have been used to generate Physical Unclonable Functions (PUFs). Resistive memory devices exhibit subtle random differences in operational parameters from cell-to-cell due to the stochastic nature of the formation of the conducting pathway. However, the inherent plasticity of such devices may not be suitable for all forms of PUFs, particularly those which rely on different characteristics from device-to-device but extremely stable characteristics for each individual device.

Invention Description

Research at Arizona State University has resulted in the design of a metal-insulator-metal (MIM) structure for PUF generation that addresses the variability concerns with the resistive memory approach. By depositing a non-stoichiometric silicon-rich SiOx (where, for example, $1.2<x<1.6$) film between non-oxidizable metal electrodes, electron current flow can be achieved at relatively low voltage. This is enabled by the percolation pathways formed by nanoscale silicon-rich zones, characterized by low oxygen concentration, Si-Si bonding, and higher local conductivity. Because the positions of these zones are random and without long-range order in the material, current flow/magnitude differs slightly from device-to-device for a given applied voltage, and provides the required stochasticity for PUF generation.

The omission of the mobile metal components (e.g., Cu, Ag) characteristic of RRAM eliminates switching capability and thus the unwanted plasticity. However, this low-cost approach still readily allows Cu-SiOx RRAM devices to be fabricated on the same IC by the use of an additional mask that determines material of one of the electrodes—oxidizable metal for RRAM and non-oxidizable for the PUF device.

Potential Applications

- Digital key generation
- Cybersecurity
- Internet of things (IoT) devices

Benefits and Advantages

- Exhibits stochastic behavior from device-to-device that is not dependent on process variations
- Exhibits stable characteristics over time at reasonable operating temperatures (e.g., up to 125 °C)
- Operates at low voltage (e.g., 1 V) and current (e.g., 100 nA)
- Low cost and completely compatible with standard CMOS processing and equipment

Faculty Homepage of Professor Michael Kozicki