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Enhanced Electrodeposit Growth Rate in Oxide-Based Lateral Programmable Metallization Cell Devices

-Background

Lateral Programmable Metallization Cell (PMC) structures have a wide range of potential applications. These devices rely on the electrodeposition of metal in a channel comprising a solid electrolyte between a pair of electrodes – an oxidizable anode that supplies metal ions, and a cathode that supplies electrons to the redox-based deposition process. The electrodeposit changes the electrical, chemical, and mechanical properties of the channel region. This can be used in switches, micro-electromechanical systems (MEMS), and valves in microfluidic devices.

The inexpensive integration of PMC elements into circuitry has been attempted by utilizing materials that are already widely used in the semiconductor industry such as copper (Cu) and oxides of other common materials. However, the low diffusivity of Cu in these oxides results in the separation of the region where ions are the most abundant (close to the anode) from the electron supply (cathode). This greatly slows the electrodeposition process to the point where it is essentially non-existent at normal operating voltages for integrated electronics.

Invention Description

Researchers at Arizona State University have developed a novel bilayer solid electrolyte (BSE) made of copper oxide/copper-tungsten oxide (Cu2O/Cu-WO3). The BSE is formed by the oxidation of a thin copper film on a tungsten-oxide layer, and simultaneous diffusion of copper into the tungsten oxide at moderate processing temperature in an oxygen or air ambient until all the metallic copper is consumed. This step creates a copper-tungsten oxide solid electrolyte which supplies the copper ions for the electrodeposition process and creates a semiconducting copper oxide layer that brings electrons to where the ions are the most abundant. This greatly increases the electrodeposition rate of the electrolyte. The materials and fabrication processes used for this invention are completely compatible with current back-end-of-line (BEOL) approaches in the semiconductor industry.

Potential Applications

- Integrated circuits (ICs)
- Memory and selector devices
- RF switches
- Microfluidic valves
- Tuning elements in micro-electrical-mechanical systems (MEMS)

Benefits & Advantages

- Minimal processing of materials required
- Ability to tailor characteristics of BSE (e.g., resistance of the Cu2O layer) to control growth rate of electrodeposit
- Applicable for many types of oxide electrolytes

Published Patent Application: https://patents.google.com/patent/WO2021222742A1/en