Chalcogenide glassy semiconductors – could they replace silicon in memory devices?

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At present, several firms such as Intel, Samsung and others are working on flash memory devices based on phase-change memory (PCM) cells, which is a promising device for nonvolatile technology. The PCM cell operation is based on the phase-change properties of a chalcogenide glassy semiconductor – as a rule $Ge_2Sb_2Te_5$ (GST). A large cycling endurance of 10^{12} cycles has been demonstrated, indicating that the PCM cell may be a good solution for nonvolatile memory applications. Phase-change memory in the chalcogenide glassy semiconductors is based on that "glass–crystal" phase transition that has been known since the mid-1960's and has now attracted great new interest in the beginning of this 21st century. So the aim of this paper is to consider the reasons for this: what has happened in microelectronics to prompt scientists and technologists to consider the phase-change memory cell as an alternative to silicon-based flash memory devices?

First of all, a brief review of chalcogenide glassy semiconductor physics, switching and memory effects will be presented. Then the properties of the "off" state (low conductivity of glassy semiconductor) and "on" state (high conductivity of metallic crystal) will be analyzed, with a special emphasis on the non-linearity of current-voltage characteristics in the "off" state. Preliminary research has shown that information recording based on crystal-glass phase transition, which is induced by a pulse of electric field in the chalcogenide glassy semiconductor, has the following peculiarities. The metallic crystalline state ("on" state) does not arise directly from glassy semiconductor "off" state, but rather through an intermediate disordered metallic type state. This intermediate state is due to the switching effect in thin films, which have strong non-linear current-voltage characteristics. The switching effect, in turn, may be strongly influenced by current filament characteristics, *i.e.* the area where memory state arises.

Properties of the "on" state and microscopic mechanisms of switching and memory effect will be discussed, followed by a comparison of Si-based and chalcogenide based memory cells. The distinction between volume properties and properties of the thin current filament region will be discussed. The electronic-thermal theory of switching and memory effects predicts micrometer size current filament regions. Then, by using the nanometer-size devices, current filament formation can be prevented, resulting in a homogeneous current distribution. It will be shown that current–voltage characteristics (CVC) calculated in the framework of electronic-thermal theory with homogeneous current distribution agree well with experimental data. Possible improvements in electric field recording by avoiding the S-shaped CVC and the decrease of the glass-crystal transition temperature due to electric field will also be discussed.

To summarize, this presentation will argue that the answer to question in the title may be positive.