Frequency multiplication of microwave signal and spontaneous electrochemical nanostructure formation in Ag-Ge-(Sb)-Te

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ABSTRACT

Amorphous and crystalline Ge-Sb-Te are emerging not only as materials for optical storage, but also for nonvolatile memory, phase-change-based radio frequency (RF) switch, and electrochemical metallization memory whose operation relies on electrochemical migration of Ag or Cu. The electrochemical process inherently exhibits nonlinear current-voltage (*I–V*) characteristics. However, little effort has been devoted to utilize the nonlinearity for the development of RF devices. In this paper, we present a successful operation of frequency multipliers based on the nonlinearity. In addition, we also report on the near room-temperature growth of novel self-organized nanostructures formed via electrochemical reactions between Ag and (Ge)-Te.

First, we show a successful frequency multiplication for Ag/$Ge_{17}Sb_{29}Te_{54}$- and Ag/GeTe-based devices under both unbiased and biased conditions. The $Ge_{17}Sb_{29}Te_{54}$-based device performs 6^{th} harmonic multiplication for 160MHz input at 5 dBm under unbiased conditions without any matching circuit. The Ag/GeTe-based device provides 4^{th} harmonic multiplication for a 0 dBm input, biasing at the resistance switching voltage of 0.4 V. The bias voltage dependence of the frequency multiplication clearly reflects the nonlinear *I–V* curves. Further optimization of the frequency multiplication is likely to pave the way for novel RF devices combined with the phase-change and/or memristive characteristics.

Secondly, we report on the near room-temperature growth of Ag-(Ge)-Te nanostructures by RF magnetron sputtering using Ag nanoparticles as the seed. Size-controlled Ag nanoparticles were formed by thermal annealing of a thin Ag film. We demonstrate that deposition of Te onto Ag nanoparticles produces Ag-Te nanowires and snail-like nanostructures while the deposition of GeTe makes cauliflower-like nanostructures. We also discuss the reaction between Ag and (Ge)-Te, as well as the crystalline phases that appeared during the sputtering deposition.

Key words: GeTe, GeSbTe, RF device, frequency multiplication, electrochemical metallization