Electrical characterization of chalcogenide nanowires, self assembled by MOCVD

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ABSTRACT

The electrical behaviour of single GeTe and Ge-Sb-Te nanowires (NWs) grown by Au-catalyzed MOCVD in the vapour-liquid-solid (VLS) mode was studied. The compositional and structural properties of the investigated NWs were also assessed. A comprehensive analysis of the NW performance is discussed and compared with those of NWs obtained by other vapour transport techniques.

1. INTRODUCTION

Chalcogenide NWs are promising structures for implementation in scaled PCM devices, since they can lead to higher performance and lower power devices than conventional thin-film-based PCM[1], owing to the improved quality of the material[2,3,4]. While vapour transport method in tube furnaces is the most widely used deposition technique to produce self-assembled NWs, Metal-organic chemical vapour deposition (MOCVD) has several advantages in terms of process control and ease of integration into existing industrial processes. A crucial step is therefore the validation of the MOCVD-grown NW functionality. The synthesis of MOCVD-grown monocrystalline GeTe and Ge-Sb-Te NWs has been recently achieved at Laboratorio MDM[5] by employing the VLS mode[6].

2. EXPERIMENTS

NWs were deposited by a MOCVD Aixtron reactor, using the tetrakisdimethylaminogermanium, trisdimethylaminoantimony and diisopropyltelluride precursors. Au nanoislands were used to catalyze the NW formation by VLS. The properties of the NWs were preliminarily investigated both by large area (SEM, XRD, TXRF) and local area (HR-TEM, in situ EDX) analysis. A couple of Pt electrodes were selectively deposited on each end of a single NW by focused ion/electron beam (FIB) deposition. The electrical characterization was carried out by means of pulsed I/V measurement to determine the I/V behaviour, and by voltage pulse to determine the resistance gap between the SET and RESET status. Amorphous to crystalline (and vice versa) switching of the NW was achieved using voltage pulses (300 ns, 3 V) delivered to the NW.

3. RESULTS & DISCUSSSION

All NWs grew in the crystalline phase; their SEM images are displayed in Fig. 1. By using TEM electron diffraction, it was found that Ge-Sb-Te NWs grow in the hcp phase and GeTe NWs grow in the fcc phase, as shown in Fig. 2. According to TEM/EDX, the GeTe NWs have a composition close to 0.50:0.50, while the Ge:Sb:Te stoichiometry is mainly 1:2:4. To the authors' knowledge, these are the first $Ge_1Sb_2Te_4$ NWs to be synthesized by MOCVD. It is thought that, as a consequence of the particular growth conditions (pressure, temperature), this composition is energetically more favoured than the 2:2:5. In addition, both GeTe and Ge-Sb-Te NWs present no lattice defects, nor foreign contaminations detectable at atomic level.

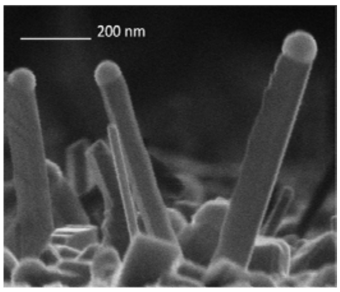

Fig. 1 – SEM image of as-grown Ge-Sb-Te NWs.

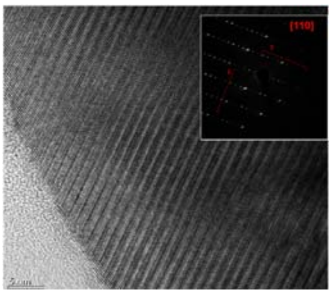

Fig. 2 – HR-TEM Image of as-grown Ge-Sb-Te NWs and related DP.

The phase change was detected by measuring the resistance of the NW, which varied by as much as 3 orders of magnitude for GeTe and ≈ 2.5 orders of magnitude for $GeSb_2Te_4$. The phase change occurred at least 10 times before failure of the device (which we ascribe to the incorporation of contaminants from the atmosphere). Although $Ge_1Sb_2Te_4$

has a lower crystallization temperature[7] and lower crystallization energy than $Ge_2Sb_2Te_5$, electrical measurements proved that, in NWs, the threshold switching voltage of the former is very close to that of the latter. The resulting pulsed I/V measurement is shown in Fig. 3 and is comparable with what obtained in $Ge_2Sb_2Te_5$ NWs grown by tube furnaces[3]. Concerning GeTe NWs, the resulting pulsed I/V plot of Fig. 4 shows that the threshold voltage is slightly lower than that of NWs obtained by tube furnaces[2].

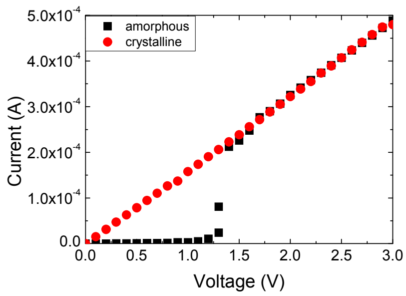

Fig. 3 – I/V of a single $GeSb_2Te_4$ NW, diameter = 80 nm

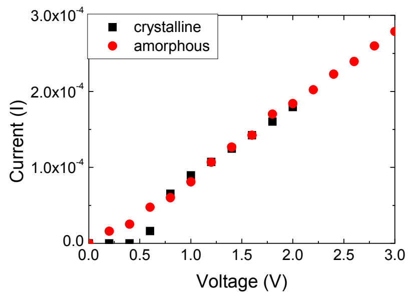

Fig. 4 – I/V of a single GeTe NW, diameter = 60 nm

4. CONCLUSION

We showed functionality of MOCVD-grown GeTe and Ge-Sb-Te NWs, exhibiting similar performances to those obtained by vapour transport in tube furnaces. Further investigations are due to test the life cycle and endurance of these devices.

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Biography

Roberto Fallica got the degree of M.S. in Electronics Engineering from Politecnico di Milano in 2007 and is currently enrolled in the “Nanostructures and Nanotechnologies” Ph.D. School at Università di Milano Bicocca. His thesis focuses on the characterization of electrical properties of chalcogenide nanowires and thin films synthesized by metalorganic vapor deposition and is being carried out at Laboratorio MDM CNR-IMM in Agrate Brianza (Italy) where he has been working since 2007. He is also responsible for thermal characterization of thin films by the 3 ω method, and for low temperature Hall characterization of chalcogenide materials.