Chemical composition and thickness homogeneity of phase change materials based thin films on an industrial-scale wafer

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Phase change material (PCM), such as germanium telluride (GeTe) from the chalcogenide family, can undergo reversible transitions between amorphous and crystalline phases when subjected to optical or electrical pulses. This rapid and reversible structural transformation makes GeTe an excellent candidate for applications such as phase-change random access memory (PCRAM) [1] and photonics [2]. A significant amount of literature has been available on the synthesis and characterization of GeTe thin films; however, most of them are focused on laboratory-scale fabrication. Transitioning to an industrial scale presents challenges in having good control of chemical composition and thickness homogeneity over a large substrate area. Here, we utilize a magnetron sputtering system to deposit GeTe thin films on 200-mm Si wafers. By optimization of sputtering process, we are specifically looking for good homogeneity of chemical composition and film thickness on a large substrate area.

In this work, we aim to investigate the influence of deposition parameters on material properties of GeTe thin films, especially on chemical composition and thickness homogeneity. The GeTe films are deposited on 200-mm Si wafers using a CS400SR sputtering cluster (Von Ardenne GmbH), with variations in sputtering power and working pressure. To determine the thickness homogeneity of GeTe film, the wafers are structured using lithography and liftoff process to form multiple measurement points from the edge to the center of the wafer. These points are then analyzed using a profilometer and atomic force microscope (AFM) (Figure 1). The chemical composition of the grown layer is measured by Rutherford backscattering spectroscopy (RBS). The phase transition of GeTe layer is identified by measuring sheet resistance with a heating wafer probe. After annealing at different temperatures, the X-ray diffraction (XRD) is used for determination of the crystallized phases of samples.

The thickness homogeneity of GeTe films is minimally influenced by sputtering power but strongly dependent on deposition pressure. Deposition at a pressure of 5 µbar results in a thickness homogeneity of 8.8%, whereas higher deposition pressures result in poorer homogeneity (Figure 2). To prevent oxidation of GeTe film, a 15-nm-thick SiN_x capping layer was deposited on GeTe film. The atomic ratio of Ge/ Te in the films deposited at 200W and 5 µbar is approximately 1.2:1, indicating uniform chemical composition across the wafer (Figure 3). In contrast, higher deposition pressures cause a low Ge/ Te ratio. For annealed GeTe films, polycrystalline GeTe could be observed in low-pressure deposited layer, while high-pressure deposited layers show the presence of GeO_2 and TeO_2, which correlate with higher sheet resistance in the GeTe layer (Figure 4). At a deposition pressure of 5 µbar, the sheet resistance homogeneity is 6.8% at 200 W and 2.8% at 100 W. The transition temperature for these layers is approximately 150 °C.

Working pressure of 5 µbar is the optimum pressure to obtain GeTe thin film with the highest thickness and chemical composition homogeneities, and increasing power from 100 to 200 W increases the film crystallinity. We find the working pressure as a critical process parameter for controlling the homogeneity of chemical composition and thickness in GeTe films deposited on 200-mm Si wafers. It is mainly due to fact that the working pressure has a direct effect on the sputtering yield difference between Ge and Te atoms. The findings obtained from these analyses will provide an experimental guidance for developing potential applications, such as GeTe-based phase-change random access memory and photonic devices.

References

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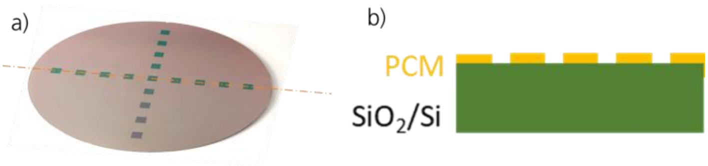

Figure 1. a) overview and b) cross section of the 200-mm wafer

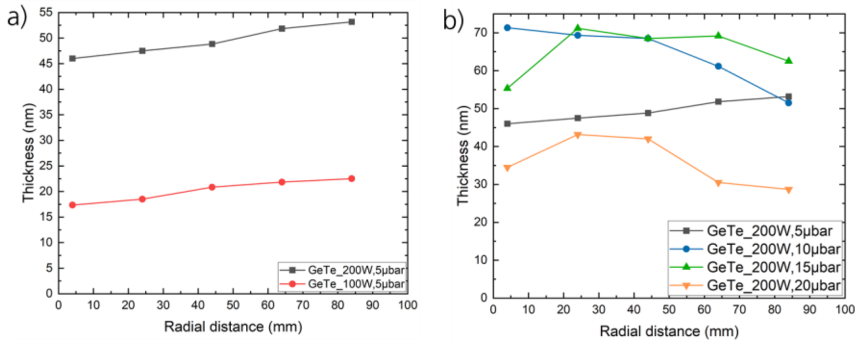

Figure 2. Thickness homogeneity of GeTe film deposited at various power a) and pressure b)

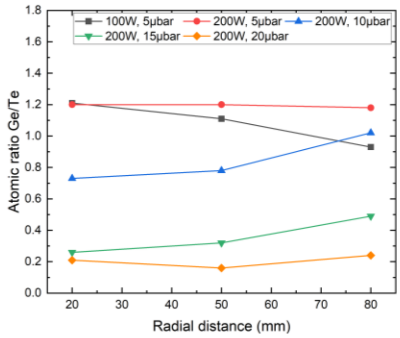

Figure 3. Atomic ratio Ge/Te of SiN_x/GeTe film deposited at various power and pressure

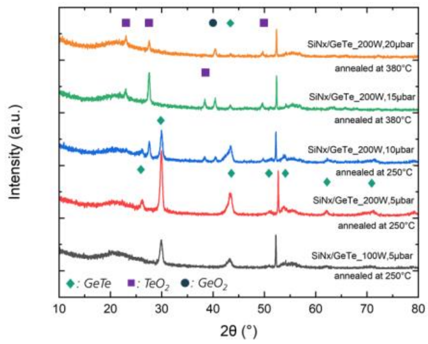

Figure 4. XRD spectra of annealed SiNx/GeTe films