Hydrogenated amorphous silicon carbide thin films deposited by plasma-enhanced chemical vapor deposition

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Abstract： Hydrogenated amorphous silicon carbide thin films (a-SiC: H) were deposited by decomposition of SiH_4 and CH_4 gas mixtures at 200 ^{0}C. Chemical bonding configuration measurements by Fourier transform infrared absorption spectroscopy show that there are SiH_n (n=1,2,3), C-SiH, non-hydrogen Si-C, Si-CH_3, and CH_n (n=1,2,3) radicals in the as-grown sample. Raman scattering measurement reveals a broad peak located at about 479.4 cm^{-1} and a weak protuberance at 970.6 cm^{-1}. These demonstrate that there aren't any crystalline nanoparticles and the sample is in amorphous feature.

Introduction

Amorphous and nanocrystalline silicon materials have recently attracted extensive research efforts as promising materials for applications in the fields of photovolataic solar cells, image sensors and thin film transistors [1,2]. When silicon nanocrystals are made very small (<~7 nm in diameter), they would behave as QDs due to the quantum confinement effect of carriers [3]. To date, considerable material fabrication work has been reported on the growth and characterization of silicon nanocrystals such as in amorphous SiO_x, SiN_x and SiC_x [4,5].

In this work, a-SiC: H thin film was deposited by decomposition of H_2-diluted SiH_4 and CH_4. The chemical bonding configurations have been measured by Fourier transform infrared absorption spectroscopy. The structural properties have been measured by Raman scattering spectroscopy.

Experimental details

The as-grown α-SiC:H samples were deposited on crystalline silicon wafer and quartz plate simultaneously. The radio-frequency of the plasma-enhanced chemical vapor deposition is 13.56 MHz. The two substrates were processed by standard RCA cleaning technology. Additionally, the native surface oxide was removed from the silicon wafer by diluted HF acid (5%) dip for 180 s. Prior to deposition, the base pressure was evacuated down to about 4×10-5 Pa by mechanical pump and molecular pump. Float rates of 50 sccm H_2-diluted 10% SiH_4 and 10 sccm pure CH_4 were then introduced into the deposition chamber to maintain a working pressure of 0.8 Torr. The other parameters: the substrate temperature 200 ^{0}C, the power supply 160 $mW.cm^{-2}$, the deposition time 60 min, were kept constant during the deposition process.

Results and discussion

Fig. 1 shows the Fourier transform infrared absorption spectroscopy of the sample. Two prominent absorption bands could be observed: one band is around 2085 cm^{-1}, the other extends from 500 to 1200 cm^{-1}. The band around 2085 cm^{-1} could be assigned to SiH_n (n=1,2,3) and/ or C-SiH stretching vibration mode [6]. The band extending from 500 to 1200 cm^{-1} could be ascribed to superposition of the following four absorption components: SiH_n (n=1,2,3) rocking and wagging mode near 655 cm^{-1} [7], Si-C non-hydrogen rocking and/ or wagging mode or $Si-CH_3$ stretching vibration mode near 780 cm^{-1} [8], SiH_2 bending vibration mode at 800-900 cm^{-1} [9], CH_n (n=1,2,3) wagging or bending vibration mode near 1000 cm^{-1} [10].

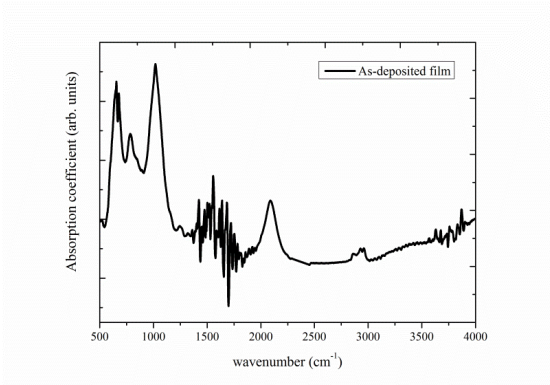

Fig. 1 Fourier transform infrared absorption spectroscopy of the as-grown sample in range of 400-4000 cm^{-1} with a resolution of 4 cm^{-1}.

Fig. 2 manifests the Raman scattering measurement of the as-grown sample. Before measurement, the system was calibrated with a single crystal Si wafer, which had a clear peak at around 520 cm^{-1}. For the as-grown sample, the spectrum exhibits one broad peak at 479.4 cm^{-1} and another weak protuberance at 970.6 cm^{-1}.

It is well known that atomic hydrogen dissociates the precursor mixtures SiH_4 and CH_4 via electron impact reactions in the chemical vapor deposition chamber. The infrared absorption spectrum reveals there are abundant charged hydrogenated silicon radicals and reactive $Si-CH_3$ species. The radicals lead to the formation of primary amorphous Si nuclei in the as-grown film. Amorphous silicon films could be characterized by a broad Raman peak at 480 cm^{-1}. Thus, the appearance of a similar band at 479.4 cm^{-1} could be attributed to the scattering by transverse optical (TO) mode of Si-Si and/or Si-C vibrations in the amorphous phase. Considering that amorphous SiC vibration density of states in Raman spectrum is up to about 900 cm^{-1}, the maximum optical phonon energy of crystalline SiC is about 972 cm^{-1}, the origin of the 970.6 cm^{-1} peak could be attributed to Si clusters (two-phonon process) with a small quantity of SiC particles.

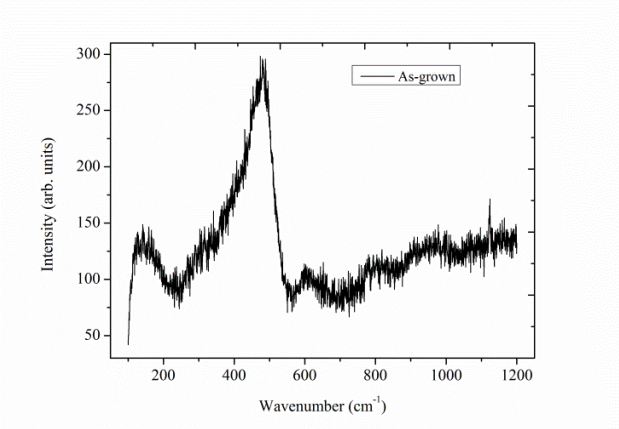

Fig. 2. Micro-Raman spectrum measured on the as-deposited sample in range of 100-1200 cm^{-1}.

Conclusions

Hydrogenated amorphous silicon carbide thin films (a-SiC: H) were prepared by decomposition of precursor gases SiH_4 and CH_4. Chemical bonding configuration measurements show that there are abundant SiH_n (n=1,2,3), C-SiH, non-hydrogen Si-C, Si-CH_3, SiH_2, and CH_n (n=1,2,3) radicals. Raman scattering spectroscopy reveals that there are two peaks, one is at 479.4 cm^{-1}, the other is at 970.6 cm^{-1}. Raman scattering shows that the as-grown sample is in amorphous feature.

Acknowledgement

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