Low Energy Inductively Coupled Plasma Etching of HgCdTe

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ABSTRACT

The high-density inductively coupled plasma etching technique was applied to HgCdTe, while using the RF-powered wafer electrode to provide low plasma energy. By using a $CH_4/H_2/N_2/Ar$ chemistry the HgCdTe etch profiles were studied as a function of mask selectivity, chamber pressure, gas ratio and ICP power. The etch rate was found to decrease as etch depth increasing. The LBIC and I-V measurements were employed to investigate the electrical damage of HgCdTe material caused by plasma bombardment .

Key words: inductively coupled plasma etching, HgCdTe, low energy

1. INTRODUCTION

The II-VI semiconductor material HgCdTe has long been used in fabricating high performance infrared detectors. The current development of infrared device processing technology revolves around the reticulation of planar HgCdTe heterojunction epilayers into mesas and the deep isolation trenches of muti-colour detectors. To meet these demands, plasma dry etching technique is required. Dry etching has significant advantages over wet etching, in anisotropic etched profile, controlled etch depth and greater uniformity. However, HgCdTe, due to its weaker crystal strengths and greater defect density, can suffer from extensive electrical and physical damage from ion bombardment. Therefore etching such material does not only require anisotropic etched profile but also lower damage. Inductively coupled plasma (ICP) etching is a high-density plasma-etching technique in which ion energy and Ion density can be controlled separately. This work investigates the possibility of etching HgCdTe at very low ion energy while also obtaining an anisotropic etched profile.

2. EXPERIMENT DETAILS

The experimental studies were carried out on System 80plus ICP65 from Oxford Instruments Plasma Technology. RF power (13.56MHz) was applied to both ICP source and substrate electrode to generate the etch plasma. An electrostatic shield around the ICP tube was used to ensure that the ICP power was purely inductively coupled (i.e. ‘true-ICP’), hence eliminating sputtering of tube material and minimizing unnecessary high-energy ion damage to

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samples. Ion energy at the substrate was monitored by measuring of the DC bias generated on the lower electrode, and was controlled mainly by the RF power supplied to this electrode. Backside cooling was used to help maintain the sample temperature through processing. The most commonly used etchant gases for HgCdTe, $CH_4/H_2/N_2/Ar$[1-3] were induced into the chamber to produce plasma, $H_2/N_2/Ar$ from a gas inlet while methane from a gas ring. The samples used were molecular beam epitaxiy (MBE) grown $Hg_{1-x}Cd_xTe$ (x～0.3) on <211>-oriented CdTe (grown by MBE) / GaAs substrate. All the samples were patterned with a masking layer based on the design for HgCdTe FPAs. Etch rates were determined by high-resolution, step-profile system, and a Tescan SEM was employed to observe the surface morphology and mesa profile.

The etching selectivity, defined as the ratio of HgCdTe-etch-rate to mask-etch-rate, is an important issue if an excellent deep-etch anisotropy and accurate replication of mask dimensions into the etched layer is needed. Two kinds of mask material were investigated the etching selectivity.

The etched samples were measured with Laser Beam Induced Current (LBIC) system to investigate the electrical damage. An alternative electrical assessment, the I-V curve of etched region and the non-etched region, was also obtained from the samples.

3. RESULTS AND DISCUSSION

Etching selectivity was found to be different with the mask material. Photoresist (PR) mask was found to be etched faster than HgCdTe, as shown in Fig.1. The etched depth of HgCdTe was about 2.7 m while the PR layer of 4 m-thick was almost "washout". The selectivity was about 0.7. The selectivity of Silica mask was found to be greater than 20, as shown in Fig.2. So the preparation of a high-selectivity mask-layer is very important before deep etching.

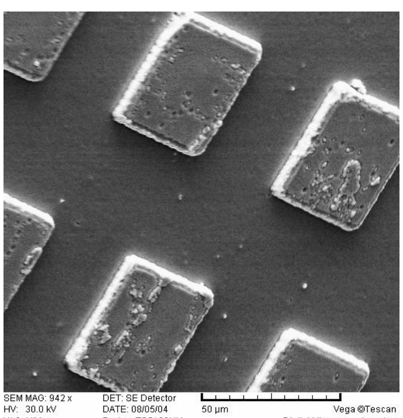

Fig.1 PR mask

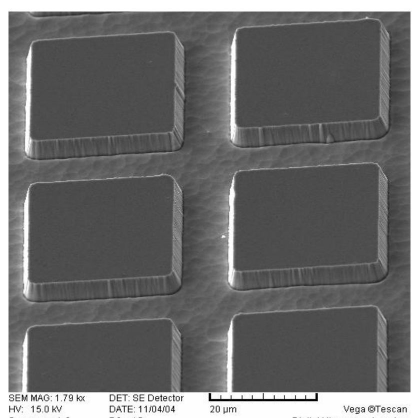

Fig.2 Silica mask

During the $CH_4/H_2/N_2/Ar$ plasma process, as shown in Fig.3, the etchant species diffuse to the surface, being absorbed and reacting with the surface, then desorb to the bulk and pumped out. Methyl(CH3) radical and H react with the

HgCdTe surface to form volatile compounds. Argon is added as a diluent and to stabilize the plasma. Ar-ion bombardment

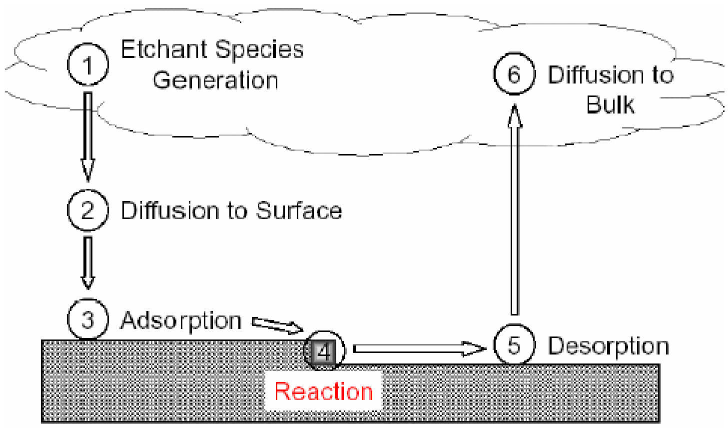

Fig.3 Process of plasma etching

of the sample is specifically confined by the DC bias. The N_2 is added to reduce polymer deposition by eliminating polymer precursors(CH_2, CH, C_2H_2, and C_2H_4) with gas-phase reactions, as proposed by Keller et al [4,5] . In essence, the process involves a competition between etching and polymer deposition. During the etching, there also involves a competition between the chemical reaction and physical ion-bombardment. In this paper, the gas ratio, the chamber pressure, the DC bias and the ICP power were adjusted to improve an anisotropic smooth etching profile.

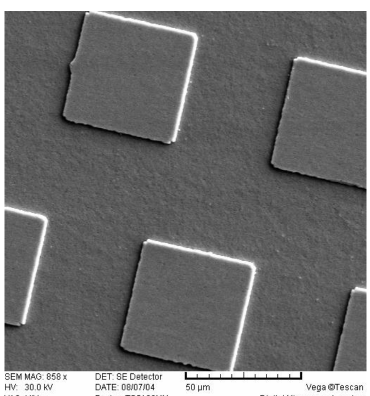

Fig.4 chamber pressure=3mTorr

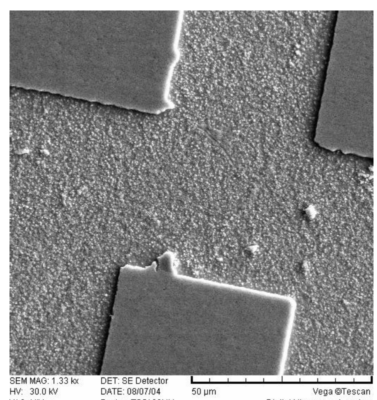

Fig.5 chamber pressure=10mTorr

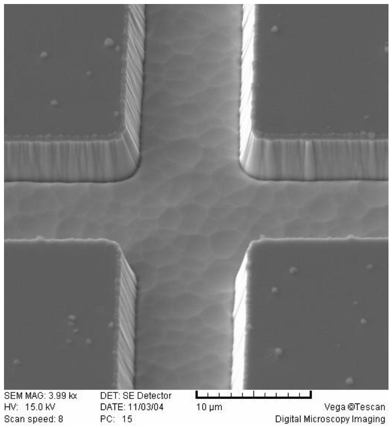

Fig.6 CH_4:H_2:N_2:Ar =1:0:5:20

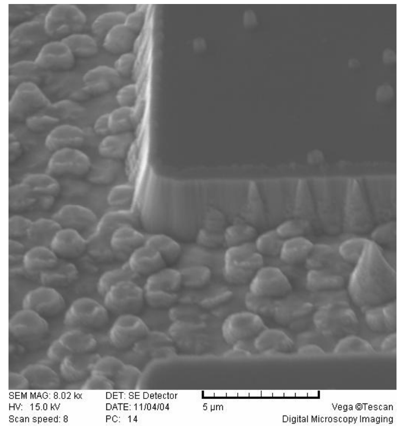

Fig.7 CH_4:H_2:N_2:Ar =2:0:5:20

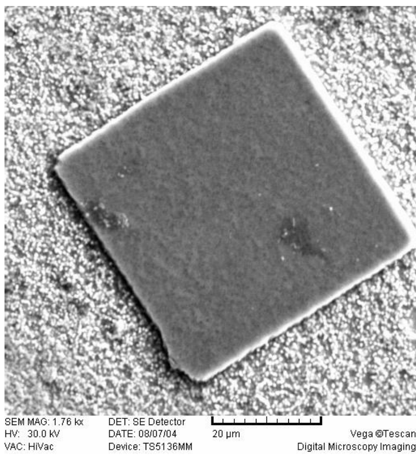

Fig.8 CH_4:H_2:N_2:Ar = 0:2:5:20

Fig.4～Fig.8 illustrate the SEM images of the etching surface under different conditions.

The etch rate was found to decrease as etch depth increasing, as shown in Fig.9. This phenomenon could be understood that as the etch depth increasing it was more difficult for the reaction products to diffuse out and for the etchants to reach the etching surfaces.

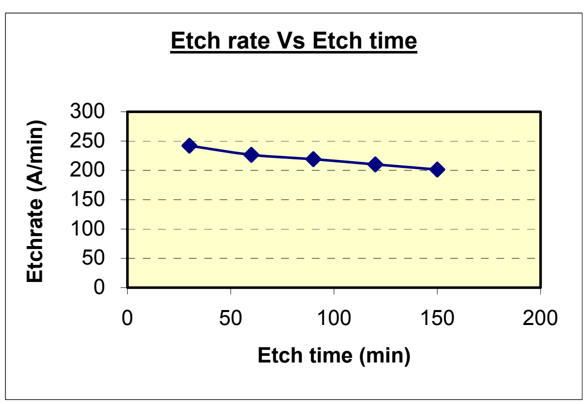

Fig.9 Etch rate Vs Etch time

As the ICP power increased from 300W to 500W, the etch rate was found to increase evidently, as seen in Fig.10. While increasing the ICP power the density of plasma discharges (including the organic radicals, ion species, atomic hydrogen) increased evidently, in hence the chemical reaction and physical ion-bombardment also increased.

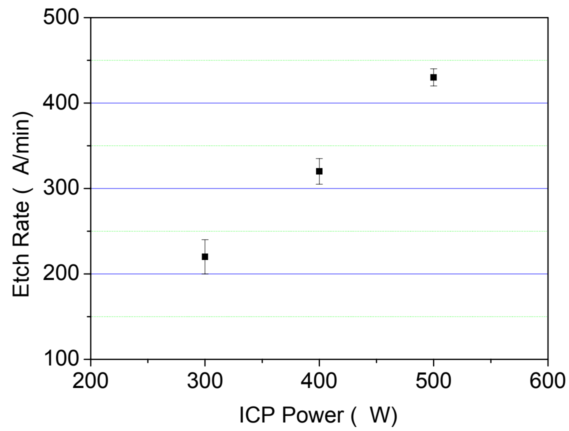

Fig.10 Etch rate Vs ICP power

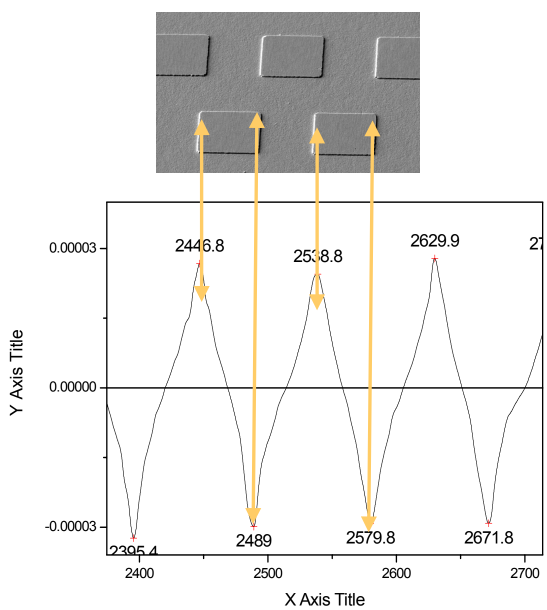

Fig.11 LBIC measurement of the etch sample

During the dry-etching of HgCdTe, besides an anisotropic smooth etched profile was needed, maintaining the electrical properties of HgCdTe was also important. In this paper, the damage of mesa-delineated samples by dry plasma etching were estimated by using a technique of Laser Beam Induced current (LBIC). As it can be seen in Fig.11. Although the plasma energy was very low (DC Bias was about 60V), the etched region was damaged electrically.

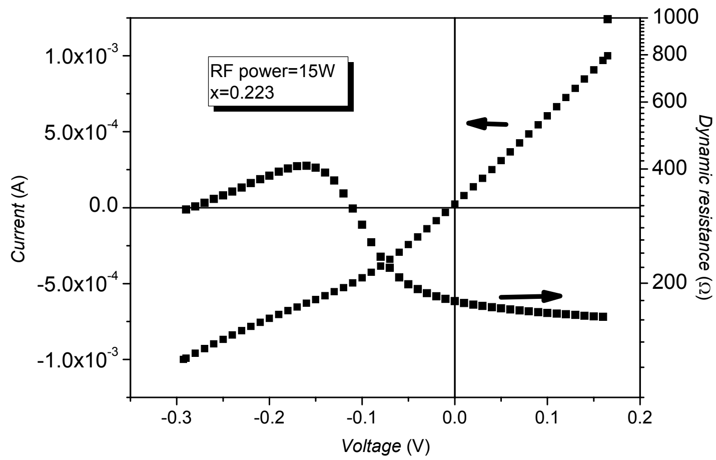

Fig.12 I-V Curve of etched sample

Initial I-V electrical assessment was obtained from above etched sample as shown in figure 12. The I-V curve is not a perfect linear one, indicating that the material had changed a little after ICP etching. Process parameters should be optimized more to minimized the effect.

4. SUMMARY AND CONCLUSIONS

This paper investigated the low energy ICP dry etching technique of HgCdTe initially. Evaluation of mask-etching-selectivity showed that silica has higher selectivity than PR. The ICP process parameters such as RF power, chamber pressure, gas ratio, and ICP power were adjusted to compromise the effects of chemical reaction and physical ion-bombardment to obtain an anisotropic smooth etching profile. Etch rate was found to be a function of ICP power and decreases with the depth increases. LBIC and IV measurements indicated that although the plasma energy was very low, the etched region was damaged electrically, process parameters should be optimized more to minimized the damage.

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