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Fabrication of HgCdTe-CdTe-Au MIS Structures

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Abstract: ***This study presents the fabrication methodology for HgCdTe/CdTe/Au metal-insulator-semiconductor structures intended for interface property investigation in HgCdTe infrared device applications. The fabrication process includes wafer mounting, mechanical polishing, chemo-mechanical polishing, optional photo-thermal annealing, CdTe passivation, post-annealing, and deposition of gate and back contacts. Critical processing parameters affecting surface quality and interface integrity are described. The fabricated MIS structures are intended for subsequent electrical characterisation, including capacitance-voltage analysis, to evaluate interface behaviour and fixed charge characteristics in the HgCdTe/CdTe system.***

Keywords: MIS Structures, HgCdTe and CdTe, Infrared Detectors, Chemo-mechanical Polishing and Capacitance Voltage Characterisation

1. Introduction

Passivation of HgCdTe is a critical step, especially for small area devices used for imaging applications, (1-3) in fact passivation of MCT surface has been a major challenge in the optimisation (4-5) of MCT devices. The fabrication of stable high performance MCT infrared devices is critically dependent upon the control of surface electrical properties (5). Surface passivation of MCT is particularly difficult in view of the complex chemistry and temperature sensitivity of this material. During the previous decade, various materials like ZnS (6-10) SiO_2 (11-17) and SiN_4 (18) have been used for passivation of MCT photodiodes. In this project CdTe is used as passivating material for MCT photodiodes. CdTe was expected to be a better choice than ZnS, Sio_2 or Si_3N_4, since it is a wide gap material, nearly lattice matched and chemically compatible to MCT. Also it is transparent to IR radiation, not hygroscopic and mechanically harder than MCT. The role of a passivant is to reduce the number of dangling bonds thus reducing the generation centers, recombination centers and traps at the interface and in the case of MCT, CdTe was considered a suitable choice. The detailed study of the various steps involved in the fabrication of MIS (HgCdTe-CdTe-Au) structures. To understand the MIS structure of Au/CdTe/MCT system from its C-V analyses we take the Si/SiO_2, MOS structure as an analogy since this system is known to be one of the best understood MIS structures and has been investigated in great depth with a lot of information and data available along with the physical interpretations.

In our case the various characterisations and calculations have been made on similar lines as for the Si/SiO_2system, with relevant modifications made for various parameters in the equations and formulae established for the Si/SiO_2 system. The oxide fixed charges of the Si/SiO_2 structures, however, would be termed insulator fixed charges for the MCT/CdTe heterojunction of our investigations.

Fabrication of the MIS Structures:

In the fabrication of MIS structure, preparation of. MCT surface is one of the most important steps. Since MCT is a very soft and fragile material, excess pressure or stress creates a lot of damage even deep into the material, which in turn causes a lot of changes in electrical transport properties. Thus, extreme care has to be taken in preparing the wafer for device processing ' In the preparation of MCT surface, the following conditions should be taken care of:

a) Non-destructive removal of the surface (contaminated) material.
b) Avoiding impurities at the surface.
c) Maintenance of crystal stoichiometry at the surface.

We used the following steps in the preparation of MCT-CdTe-Au MIS structures given below in chronological order:

Mounting of Wafer:
The MCT wafers of diameter 10mm were cut into two halves with the help of a wire saw after mounting them on rectangular slab specimen holder using salol. The MCT surface was protected by photo resist before cutting it After cutting the MCT crystals, the photo resist from the surface of MCT was removed by dissolving it in acetone. Then the MCT wafer was taken, first cleaned with soap solution and DI water and then mounted on perfectly flat stainless steel Jig shown in Fig .1 of 4cm diameter with salol. However, we only mounted single wafer at a time.

Mechanical Polishing:
The polishing operation is the most critical step in the preparation of MCT surface. It must have the surface of the wafer perfectly flat and undamaged. We have done Polishing of MCT crystal in three phases using alumina powder of different grain size, viz., 0.1, 0.5, and 1micron. The polishing was carried out by rubbing the wafer against a cloth saturated with an abrasive material such as syton.

Polishing was done on syton polishing pads with specimen holding fixtures For making polishing slurry, approximately 50mg of alumina powder was mixed with 100ml of DI water. The polishing was carried out at a speed of about 20-25 rpm. After polishing the MCT crystal is inspected under an optical microscope for scratches and smoothness of the surface.

Chemo-mechanical Polishing:
Chemo-mechanical polishing was carried out using polishing pads with specimen holding fixtures and specially mounted etchants. The principal advantage of chemical polishing over mechanical polishing lies in the fact that it reduces sub-surface damage to the crystal structure. In mechanical polishing fine scratches are introduced into the material which are associated with dislocations and deformation of the

material. As polishing proceeds with finer polishing agents, the surface quality improves until no defects are visible under a microscope. However, this appearance can be very misleading since considerable damage can still exist in the form of filled in scratches, micro-cracks, pits and dislocations concealed by the surface flow of the material being polished. The area of micro-cracks hidden by layer represents damage which has not been yet removed by polishing process. A 0.5% Bromine-Methanol solution was used for chemical polishing. Since the chemical used is highly toxic and aggressive, the chemo-mechanical polishing has been done on polishing pads with specimen holding fixtures. Careful handling of Bromine-Methanol solution is essential in order to improve the level of safety during use. A neutraliser Ammonia is added to the waste sump of chemo-mechanical polishing before draining out Bromine. During this process a continuous supply of free etchant is used for the elimination of consumed material. Around two microns of stock was removed in this process. The wafer was then demounted for free etching. This has been carried out in 0.2% Bromine-Methanol solution. In this process we removed around one micron of stock. The prepared surface was characterised using ellipsometer.

Photo-thermal Annealing:
Some MCT wafers after polishing were subjected to photo-thermal annealing. The photo-thermal annealing was carried out in a Samco Plasma Deposition System Model PD-2S (fig.2). For photo-thermal annealing the MCT wafers were kept at substrate temperatures of 80°C or 100°C in the presence of UV photons and hydrogen gas was bubbled through a Hg-boat. MCT wafers were annealed for different durations with the Hg bath temperature varying from room temperature to 150°C for different durations. The hydrogen pressure in the chamber was maintained at I mbar.

Passivation of MCT:
The prepared MCT surface was passivated by depositing CdTe on it. The CdTe thin film was deposited by Flash Evaporation technique under a vacuum of $8x10^{-6}$mbar. The boat temperature at the time of deposition was 1400 °C. The thickness of the deposited films was monitored with the help of a crystal oscillator. The CdTe films deposited on MCT had thicknesses ranging between 2000 and 3700Å

Post Annealing:
Post annealing was carried out for different durations with the MCT/CdTe structures heated to 80°C and 100°C in order to optimise the annealing conditions. Some of the samples after pre-annealing were subjected to post-annealing after deposition of CdTe while some samples were not post annealed after depositing CdTe by flash evaporation technique on the polished MCT but only pre-annealed. It may be mentioned that, unlike pre-annealing, where the H_2 was bubbled through a heated Hg - boat, for all the post-annealings, the Hg-tub was not used and post-annealing was carried out in H_2 atmosphere at different annealing temperatures and durations.

Gate Electrode:
Au (metal gates) of thickness ~ 700Å were deposited through an aluminium mask by thermal evaporation at a vacuum of ~ 10^{-6} torr.

Back Contact:
Ohmic back contacts of gold were made on the back face of MCT crystals by electroless deposition of gold chloride. The fabricated MIS capacitor consisting of p-type MCT, an ohmic back contact of electroless deposited gold chloride, thin insulating layer of CdTe and a Au gate electrode is Shown in Fig 3 and steps involved in the fabrication of MIS (MCT-CdTe-Au) Structure are shown in fig 4.

2. Conclusion

A fabrication route for HgCdTe/CdTe/Au MIS structures has been established with emphasis on surface preparation, passivation, and thermal treatment. Surface conditioning and CdTe passivation are identified as critical steps for achieving stable interfaces. The fabricated structures provide a platform for subsequent electrical characterisation of interface properties relevant to HgCdTe infrared device development."

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Figure 1: MCT Wafer mounted on jig for Polishing

Figure 2: Schematic Plasma Deposition System used for photo-thermal annealing of MCT sample

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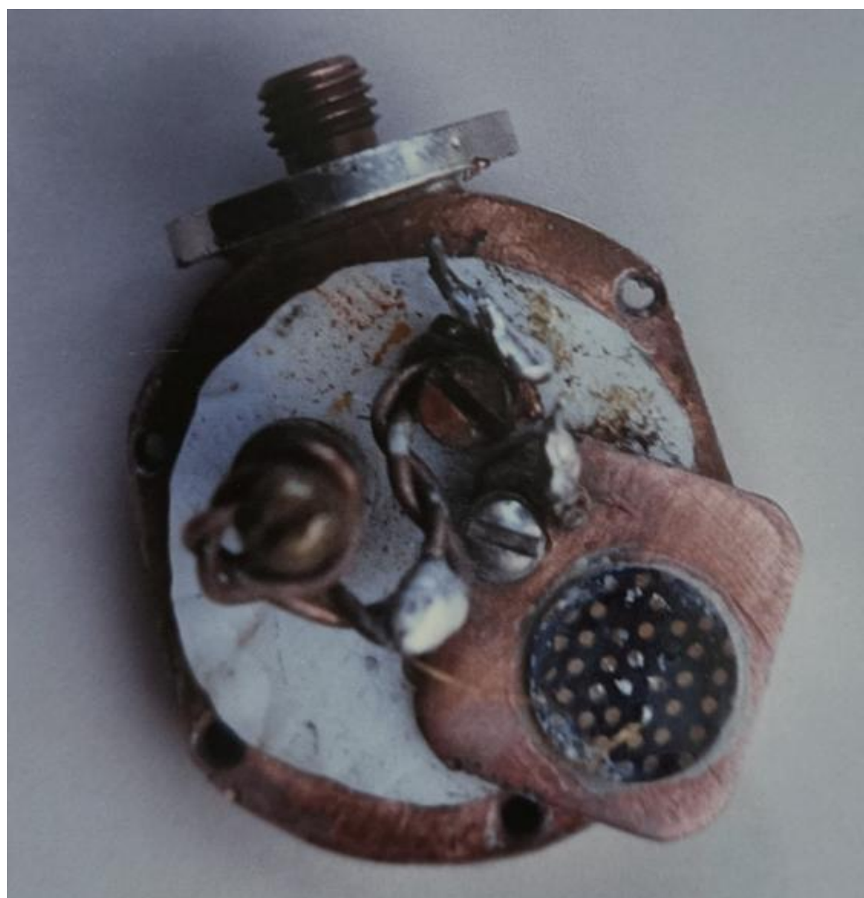

Figure 3: Au-CdTe- HgCdTe MIS Structure on Copper Plate

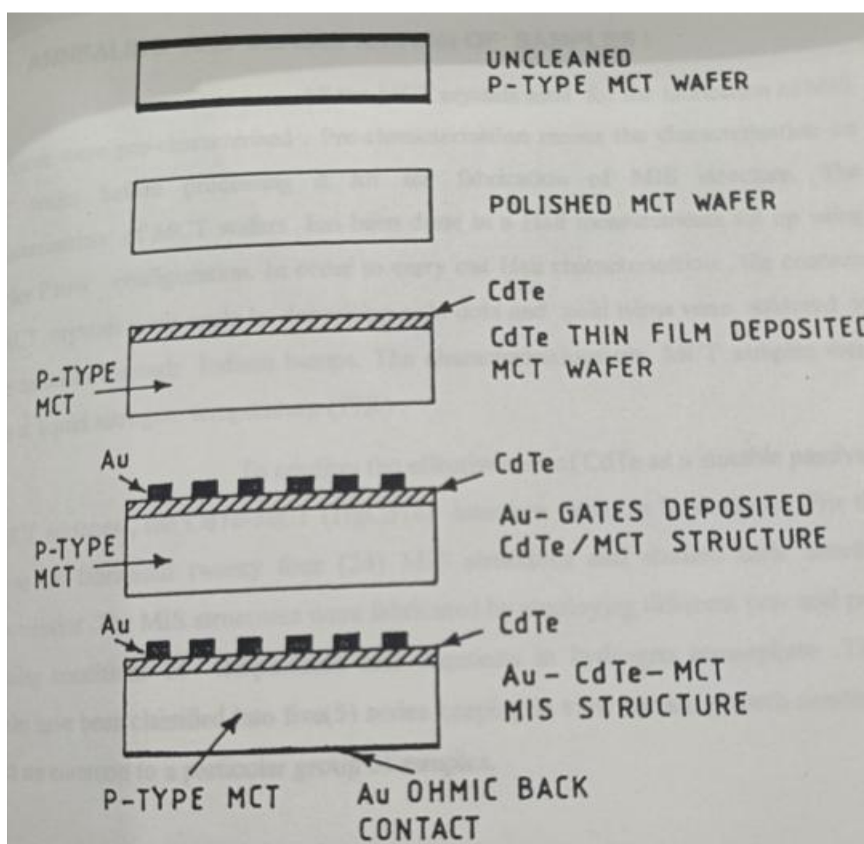

Figure 4: Steps For Fabrication of MIS Structure Au-CdTe- MCT