Investigations on Molybdenum disulphide films coated on Si sheets grown using capillary action shaping technique

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Abstract

Commercial Silicon wafers and multicrystalline Silicon sheets grown by capillary action shaping technique (CAST) were coated with thin molybdenum disulphide (MoS_2) films by thermal evaporation under vacuum. The films were characterized using optical microscopy and x-ray diffractions (XRD) techniques. It was found that the MoS_2 films coated on commercial Si wafers single crystalline nature where as those coated on CAST sheets multicrystalline nature. It is concluded that high quality and low cost MoS_2 films could be grown on Si wafers by vacuum deposition technique.

Key words: Si wafers, MoS_2 films, vacuum deposition evaporation

1. INTRODUCTION

In the first generation of photovoltaic (PV) development, primarily silicon wafer based (single crystal, multi-crystal or ribbon silicon) modules dominate the market [1, 2]. To compete with conventional energy sources there is a need for the reduction in the PV manufacturing costs and increase efficiency [3 – 5]. Some reports suggest that the coating of thin layer of semiconducting materials as absorber layers improves the efficiency of Si based solar cells [6, 7]. Dimroth and Kurtz [8] reported that solar electric conversion efficiency of multilayer solar cells is expected to pass 40% soon and to move toward 50% in years to come. Recently there have been reports of monolayer MoS_2 films prepared by liquid exfoliation and physical separation techniques exhibiting exceptionally good semiconducting properties and even proposed for making transistors [8, 9]. MoS_2 films coated on Si have also been proposed for energy harvesting purpose [8].

We have therefore tried to deposit MoS_2 films by vacuum deposition technique on commercial Si (111) wafers and Si sheets prepared by capillary action shaping technique (CAST) [10] that has been developed in our laboratory and the growth of LiF11 and Si12 sheets. In the present communication we report the investigation of the physical and electrical properties of these films and examine their suitability for possible solar cell applications.

2.0 Experimental Details

The CAST Si sheets grown in the laboratory have been lapped and polished to produce wafers of 1cm x 1cm x 0.6-0.8 mm thickness.

For comparison commercial (111) oriented Si wafers of the same dimensions were also used. These wafers were etched and passivated before vacuum coating as described earlier [13]. These films have been characterized using optical, metallographic and x-ray diffraction (XRD) techniques.

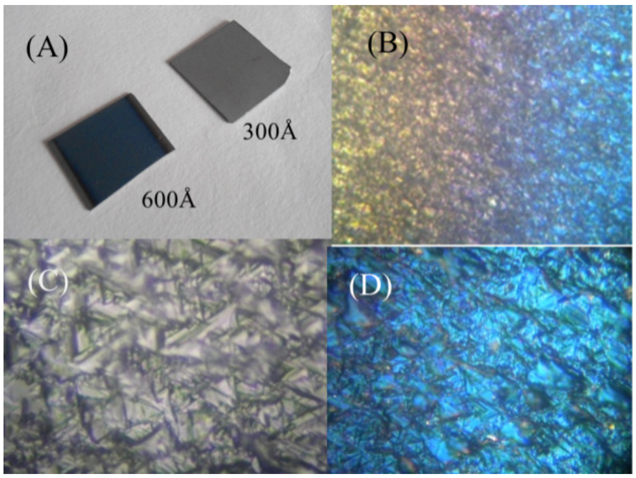

FIG. 1 (A) Photograph of the Si Sheet pieces coated with 300 Å and 600 Å thick MoS_2 film by vacuum evaporation technique, (B) the portion of the region in between the coated and uncoated regions (x200), (C) uncoated and passivated Si surface (x800) and (D) MoS_2 coated surface (x800).

3. Results and discussion

MoS_2 films were deposited on these silicon wafers using a Balzer (BAK-600) make vacuum coating chamber. The procedure for cleaning and passivation has been described earlier as mentioned above. The samples were mounted on a proper jig, MoS_2 powder was filled in the evaporating boat, the chamber closed and the pumping system started to achieve the required vacuum (10^{-5} mbar). Then the substrate was heated to 250°C and to make inert condition argon gas was passed inside the chamber. Glow discharge (plasma) is used to clean and remove the surface particles as well as surface charges.

During glow discharge vacuum reduces to 10^{-2} mbar. After the vacuum improves to better then 10^{-5} mbar the MoS_2 was evaporated by heating the boat containing MoS_2 powder to 1200°C. The coating was performed to obtain films with two different thickness 300 Å and 600Å. After achieving the proper coating thickness and after cooling down, the vacuum system was closed to take out the sample for measurements.

Fig. 1 gives the photographs of (A) the MoS_2 coated Si samples with 300 Å and 600 Å thick films, (B) gives the portion of the surface between uncoated and coated areas, (C) the optical micrograph of the Si plate surface before coating showing the etch pits on the surface and (D) the completely coated surface. It is seen from both (B and (D) that the surface features of Si are maintained even after coating with the MoS_2 film indicating epitaxial growth.

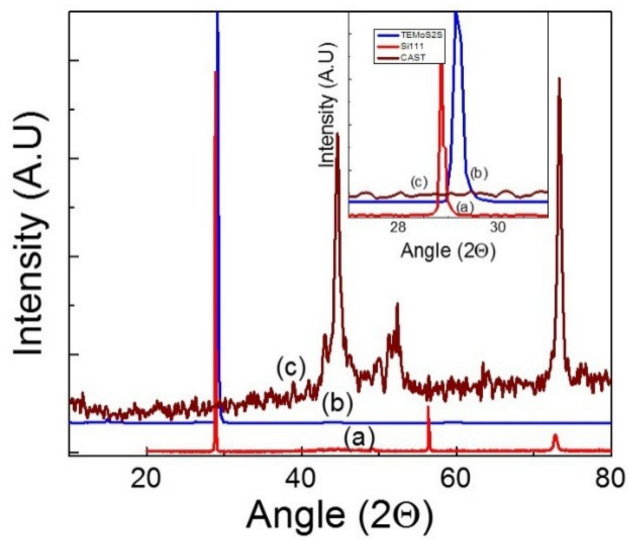

FIG. 2 XRD patterns of the Si (111) wafer (a) before, (b) after vacuum coating with MoS2 film and (c) with exfoliated MoS_2 film. Inset gives the expanded view of the (004) reflection of MoS_2 at 29.15° separated from the (111) reflection of Si at 28.86°. On the other hand in case of the XRD pattern of the multi-crystalline CAST wafer (Fig 2 (c)) the (004) reflection is not observed.

Fig. 2 (a) and (b) give the XRD patterns recorded on the Si (111) wafer before and after coating with MoS_2 film and (c) shows that of the CAST sheet coated with MoS_2 film. In case of the un-coated wafer strong (111) reflection is observed along with a weak (003) reflection. The XRD patterns of MoS_2 in Fig. (b) and (c) fit well with the hexagonal space group of $P6_3$ / mmc (77-

1716). The (004) reflection is not seen in the pattern of Fig 2(c) indicating that there is no lattice match with the surface of the CAST wafer as the orientation is different from (111) of the commercial wafer. However, the similarity of the pattern with the standard given above shows that the film is that of MoS_2 and additional peaks are not observed revealing the purity of the phase [14].

The inset gives an expanded view of the main diffraction peak to show the separation of the peaks. The strong peak at 29.15^o in the pattern Fig. 2(b) corresponds to the (004) reflection and is very close to the (111) reflection of Si at 28.78^o. The (004) reflection seen in (a) and (b) is not seen in (c). This indicates that the MoS_2 film on the Si (111) substrate and is single crystalline as it shows a single reflection indicating an epitaxial growth. On the other hand the film coated on the CAST sheet shows a multi peak diffraction pattern that is similar to a power (Fig. 2(c)) and is also fitted and indexed to the hexagonal space group referred above. This is because the CAST wafer does not offer the desired orientation for epitaxial growth.

In conclusion we have demonstrated that vacuum thermal evaporation could be used for the production of good quality and low cost films of MoS_2 on commercial and laboratory made CAST Si wafers by the characterizing them with optical microscopy and XRD techniques.

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