Optical Profile of Modified Silicon for 2D Heterostructures

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ABSTRACT

Optical analysis of irradiated silicon surface have been investigated for the growth of multi chalcogen precursor based chemical vapor deposition synthesis of 2D heterostructures. The Si-surface by 10 keV Ar^+ ion bombardment at an oblique angle incidence of 45° for various ion fluences of order ~$1x10^{17}$ Ar^+ cm^{-2} at room temperature has been done to compare the surface of silicon substrate to grow metal oxide, sulphide 2D heterostructures. Sulphide being the first layer and so on. The investigation have been done to develop the nano layer coatings of 2D hetero materials with different electron densities like 2D-TiO_2-ZnO, 2D-MnS-SnO_2. There optical properties have also been observer as a key parameter to study the optical porocity for electronic sensors with wide tunable performance.

KEYWORDS: Layered 2D Heterostructures, Optically Active Layered 2D Materials, Sensors.

INTRODUCTION

In contrast, the term heterostructure can be defined as heterojunction or heterointerface formation by stacking two different materials. 2D heterostructures are very sensitive layer for electronic transport of charge carriers such as spin charge and valley [1]. A 2D heterostructures can be formed by layering different materials like Si-MnS, SnS, SnS_2, ZnO, Si-TiO_2, Si-SnO_2, Co_3O_4, WO_3, etc [2, 3]. The properties of these oxides and sulphides change upon exposure and contact to various layers [4]. The search for new development has given rise to rapid advances in semiconductor material technology recently by changing the materials and investigation for different properties associated with them such as optical [5, 6]. These semiconductor material based modified layers provides many advantages for continuous development and is easy to integrate with existing material systems. But, the development of materials for wide bandgap is very important and is very limited to inorganic semiconductor materials. Some transition metal oxides are quite inert because they have large bandgaps. [7, 8] Neither electrons nor holes can easily be formed in their sites. With these new stacked heterostructures, their physics and chemistry as two inseparable sides of a coin have emerged and attracted the scientific community to point out new insight into the phenomena [9, 10]. Special interests and their potentials drive the development of 2D heterostructures. [11] 2D heterostructures support a wide range of building blocks with exotic optical, electronic and mechanical characteristics [12, 13, 14]. In 2D heterostructure semiconductors, quantum confinement effects arise from their atomically thin nature of layers, leading to different physical phenomena driven by electrons confined to move in X-Y plane due to their high surface-to-volume ratio and atomic thickness, 2D heterostructures exhibit strong light–matter interactions, allowing for efficient photon absorption and detection.[15, 16, 17] 2D materials can also be transferred onto silicon based photonic circuits, optical waveguides, and fibers, unlike many traditional 2D heterostructures that require complex integration [18, 19]. Their dangling-bond-free surfaces ensure seamless interfacing with photonic and electronic parts.[20] One of the most promising applications of 2D materials is the development of advanced photodetectors, which play an essential role in various fields including telecommunications, environmental monitoring, medical diagnostics and radio imaging [21]. This enables applications in wearable photodetectors, optoelectronics and transparent image radio sensors. [22, 23]

EXPERIMENTAL

Cleaved silicon surface of area 1.5 cm^2 were irradiated by 10 keV Ar^+ ions at an oblique incidence angle 45˚with respect to surface normal have been done. These samples were sputtered with Ar^+ ion beam having low energy to a dose of 1×10^{17} Ar^+cm^{-2}. Electron Cyclotron Resonance (ECR) ion source was used to carry out this research. Uniform irradiation was achieved by scanning the beam over the Si (100) samples. The ion fluences were varied from 1×10^{17} to 1×10^{18} Ar^+/cm^2. The average ion beam current was around 5A. The target chamber and plasma chamber were maintained in high vacuums ~10^{-7} mbar which was reduced during irradiation. The morphology of the irradiated silicon samples were investigated using Atomic Force Microscopy (AFM), Multi-Mode AFM instrumentation. The AFM surface morphology of all the samples was taken in contact mode. The surface rms roughness and other statistical information of the surfaces were extracted from the AFM images and further statistical analysis were done to study the optical parameters of ripples.

RESULTS & DISCUSSIONS

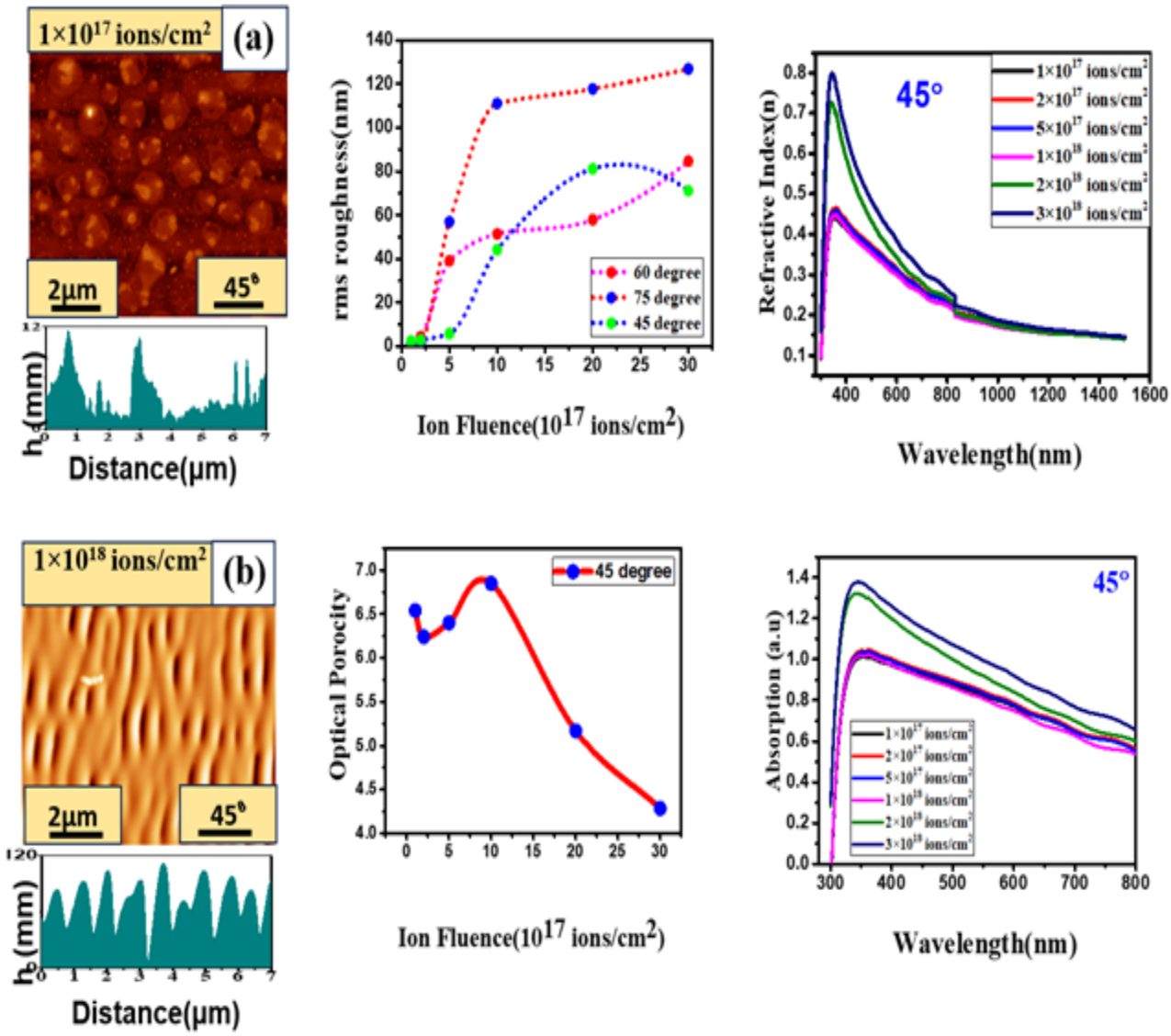

Fig 1: Surface Morphology of Si-substrate at 45˚ of various ion fluence. Calculated RMS roughness at three different angles. Refractive Index and Absorption of Silicon substrate, Optical Porocity with various ion fluence.

It is observed that longer wavelengths are not suitable for the purpose of absorption.[24] This is a key parameter for the light-material interaction on the surface. The variance of surface profile is homogeneous and monotonic with the ion fluences of order ~10^{18} $Ar^{+}cm^{-2}$.[25, 26] But the optical porocity is maximized for low ion fluence. Roughness also satisfies the normalized values at an angle of 45˚with respect to surface normal. The refractive index of the modified silicon is abrupt for lower wavelength rather than higher one. So, materials which have lower density can be deposited on the modified silicon as the first layer so that the conformity of the substrate can be maintained. Then it is possible to grow a slightly higher density, which is associated with rich electron density, can be integrated on the first layer as 2D heterostructures by chemical vapor deposition system. As this is a scalable method to produce high quality tunable 2D materials. Irradiation on silicon surface for sensor application plays a vital role in the fabrication as well as the sensitivity of the sensors [27]. An irradiated substrate enhances the capability of the sensor performance.

CONCLUSIONS

Optical selectivity is one of the critical requirements for making practical sensors made of 2D heterostrucrures. The instability in sensors causes pseudo alarms and attracts a high cost due to the replacement of materials of the sensors.[28] Refractive index of surface, response, surface roughness, surface porocity and recovery time are also very crucial for making ultrafast sensors for wavelength capturing.[29] But, in practical senerio, the widely used sensing metal oxide materials such as 2D-MnS-Cu_2O, 2D-TiO_2-

ZnO, 2D-MnS-SnO_2, 2D-MnS-Ga_2O_3, and 2D-MnS-SnS heterostructures. An ion irradiated modified surface acts as a very good surface to attract the ions and molecules.[30]

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DATA AVAILABILITY STATEMENT

All the data are provided in this research paper.

CONFLICT OF INTEREST

The authors declare no known competing interests.

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