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Electric properties of Carbon doped β-$FeSi_2$ /Si heterojunction photodiodes

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The semiconducting iron disilicide β-$FeSi_2$ has recently attracted considerable attention from both scientists and engineers due to its remarkable optical and electrical properties. β-$FeSi_2$ has a large absorption coefficient, which is 200-fold larger than that of crystalline silicon at energies above 1.5 eV, and possesses indirect and direct optical band gaps of 0.74 eV and 0.85 eV, respectively. β-$FeSi_2$ is one of the most promising materials for various applications such as light-emitting diodes, infrared photodetectors , and photovoltaic. We fabricated β-$FeSi_2$/Si heterojunctions to be employed near infrared photodiode. This hetrojunctions showed good rectifying properties with a rectification ration of more than two orders of magnitude. However, their current-voltage (I-V) characteristics exhibited large leakage dark current. We believe that the main source of that leakage current is the high carrier density, in β-$FeSi_2$ epitaxial film, which exceeds 10^{18} cm^{-3}. In this study, an effective method to reduce the carrier density is suggested. This method includes introducing carbon atoms to β-$FeSi_2$ film prepared by Radio Frequency Magnetron sputtering (RFMS) apparatus, equipped with C-doped $FeSi_2$ targets. The electric properties of the fabricated devices, is experimentally investigated.

N-type β-$FeSi_2$ films were epitaxial grown on p-type Si (111) substrates with an electrical resistivity of 10 Ω.cm and thickness 260 µm at a substrate temperature of 600 ºC by RFMS. $FeSi_2$ alloy (un-doped and 5% C-doped) targets (purity: 4N) were used as a source material for the sputtering deposition. During the sputtering process, the applied power is 20 W, the argon flow rate is 15 sccm, and the gas pressure is $2.66*10^{-1}$ Pa. In this study, RFMS apparatus equipped with load-lock transfer system was used to deposit the front and back ohmic contacts of the prepared heterojunctions. Pd (purity, 4N) was deposited on the Si surface in finger-shaped pattern, while Al (purity, 4N) was deposited on the entire β-$FeSi_2$ back surface. These depositions were carried out at room temperature. The electrodes film thicknesses were ~ 300 nm.

To investigate the epitaxial growth and crystallinity of the deposited films, they were characterized by XRD (Rigaku, RINT2000/PC) using 2θ-θ, and pole figure measurement techniques.Fig.1 (a) displays the XRD patterns of the β-$FeSi_2$ grown on Si (111) substrate. The 202/220 peak of β-$FeSi_2$ was observed in this measurement. These results confirm that the β-FeSi2 have been grown on the (111) substrate Si. Fig.1 (b) shows the pole figure pattern of the C-doped β-$FeSi_2$. The pattern indicates the existence of three types of epitaxial variant that are rotated at an angle 120º with respect to each other. From these results, β-$FeSi_2$ film was epitaxial grown not only in a direction perpendicular to but also in parallel to Si (111) substrate.

The I-V characteristics of undoped and 0.5% carbon-doped n-type β-$FeSi_2$/p-Type Si heterojunctions are shown in Fig.2. The undoped β-$FeSi_2$/Si heterojunctions shows large dark leakage current (about 2×10^{-2} A/cm^2 at bias of -3 V) and weak response under illumination of 1.3 µm light. Whereas the carbon-doped β-$FeSi_2$/Si heterojunctions showed a significant improvement in leakage current. We believe that C-doping is effective in terminating dangling bonds in β-$FeSi_2$ films and therefore reduce its carrier density.

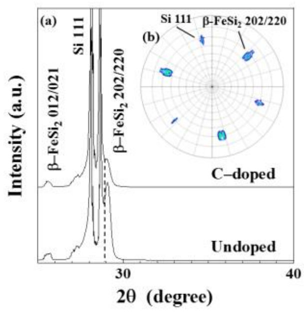

Fig.1 (a) 2θ - θ XRD patterns of undoped and C-doped β-$FeSi_2$ deposited on Si (111) Substrate. (b) pole figure patterns of C-doped β-$FeSi_2$.

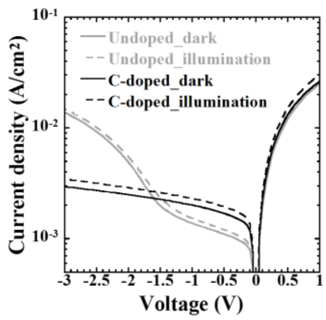

Fig.2 I-V characteristics of undoped and C-doped n-type β-FeSi2/p-type Si heterojunction diode.

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