The Study on Material Properties of Boron Phosphide

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Abstract

Boron Phosphide films were deposited on (111) Si substrate at 650 ℃, bythe reaction of B_2H_6 with PH_3 using APCVD. N_2 was carried out as carrier gas. The optimal gas rates were 20 ㎖/min for B2H6, 60 ㎖/min for PH3 and 1 ℓ /min for N2. After as grown the films were insitu annealed for 1hour in N_2 ambient at 550℃ and measured.

The measurement of AFM shows that the average surface roughness is 10.108Å for the reaction temperature at 450℃ and 29.626Å for the reaction temperature at 650℃. The measurement of XRD shows that the films have the orientation of (1 0 1). Also, the measurement of AES is shown that the films have $B_{13}P_2$ stoichiometry.

For the Result of microwaves absorbtion properties using VNA, it obtained the permittivity of BP about 8 between 1.5 ~ 2.5GHz. In this study, it obtained the BP thin film by deposited in atmosphere pressure And BP thin film can be after to applicate as microwave absorbtion material is obtained.

Key words : CVD, BP, B_2H_6, PH_3, WDX

1. Introduction

Since 1890s, BP(Boron Phosphide) have been regarded as one of III-V compound semiconductor. Early 1890s, study about composition of B(Boron) and P(Phosphorous) was begun by M. Besson etc. And in 1960s, from R. C. Vickery, R. J. Archer and V.I. Matkovich, study about BP's evaporation method and the properties of material had continuously[1-6].

In 1970s, study about crystal growth had from T. L. Chu, K. Shohno and T. Nishinaga and is accomplishing mainly study of BP until present. Since 1980s, the growth concertionwas appearer good result by C. J. Kim, Y. Kumashiro and A. Goossens[6-9].

From 1990s, until the now, achieved by H. W. Leite Alves, Yunle Gu and J. Goossens[8-9].

BP is compound semiconductor that the composition elements of group III and group V of elements. BP is very suitable to high temperature thermoelectric device that have high efficient thermoelectric conversion rate. Also, it can be used usefully as protective material because to very stable chemically and to very strong physically. In the case of thin films, for use windows layer of solar cell. When BP formed hetero-junction is deposited on silicon, for use active layer of solar cell being progressing study that to use good quality about absorption coefficient for photon thathave high energy[10-12].

Present, the deposition method is studied that by CVD(Chemical Vapor Deposition), MBD and sputtering etc. In the three cases, is following.

Firstly, It is APCVD method. In this case, BBr_3-PBr_3, B_2H_6-PH_3, BCl_3-PCl_3 is used as reaction gas and it deposited at high temperature more than 900℃.

Second, It is MBD method. In this case, B2H6 and PH3 being using reactiongas and the deposition is usually vacuum of about 5×10^{-9} Torr (vacuum value of early 5×10^{-9} Torr), and temperature is between 400℃~800℃.

Third, It is sputtering method. In this case, the method to use target by boron and PH_3 of plasma source. But the optimum deposition condition was not decided[10-12].

Therefore, BP is compound materials as stable compound semiconductor chemically and not take out at manufacturing process of semiconductor. These materials were deposited the thin film at low temperature and characteristics of the material measured, and it can apply directly in various semiconductor manufacturing process[36].

Recently, as according to the use of electron·telecommunication appliances increases rapidly, interest and worry about damage of microwaves increases that harmful effect of microwave in human body is announced. The companies are contribute to development of microwave absorbing technology for people health protection. Since 1980s, the study about microwave absorbing technology begun to be studied by doing usage lest should be sensed to RADAR. but, In the 1990s, the study for microwave absorbing textiles and the application product which protected human body from microwave.

2. Experimental

In this study, BP thin films were deposited on the (1 1 1)Si substrate using APAPCVD. 1% B_2H_6(Diborane) in H_2 and 5% PH_3(Phosphine) in H_2 were employed as reaction gas. The carrier gas used to N_2. The substrate size is 1.5 cm^2. Fig. 1 is schematic diagram by cleaning process. The substrate was cleaned using trichloroethylene ($ClCHCCl_2$), D. I. Water, acetone (CH_3COCH_3) and methanol (CH_3OH) by the ultrasonic cleaner for 5 minutes, respectively. After removed water on the substrate surface, and steamed water in the vacuum oven. next, shows to using equipment. The size of quartz reaction chamber is 40mm width, 25mm height and 400mm length. Mixed reaction gases were passed on the graphite suscepter in the quartz reaction chamber. The chamber was heated by lattice shock of the graphite suscepter that was induced by RF power. The Si substrate was located on the graphite suscepter coated SiC and then flowed reaction gases. RF power induced in the chamber, temperature was gradually increased. It was deposited at 450℃ and 650℃. Reaction gases were B_2H_6 and PH_3. Films were annealed for 1 hour in N_2 ambient. In the experiments, it found out optimum conditions of the reaction gas rate and the carrier gas rate. The optimum reaction gas rate of B_2H_6 and PH_3 were 20 cc/min., 60 cc/min., respectively. The optimum carrier gas rate was 1 l/min. Films were annealed at 400℃ and 550℃ for 1 hour for crystallization and stabilization in N_2 ambient. Fig. 2 shows the process flow chart of experiments.

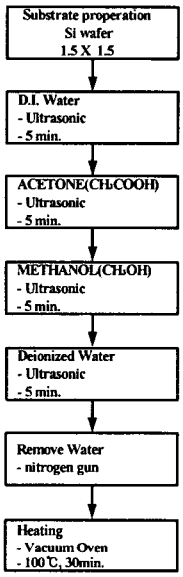

Fig. 1 Cleaning processes

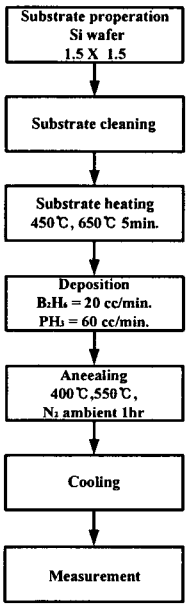

Fig. 2. Experimental processes

3. Results and Discussions

To analyze the crystal property of the BP thin film, the roughness of a surface was recognized by AFM and the orientation property of a thin film measured by XRD.

For the result of AFM the scanning area is all 10 ㎛ × 10 ㎛ with a surface to measure surface roughness of a BP thin film.

AFM image and the line profile which measured a surface of deposited BP thin film in 650 were shown in Fig. 3 The RMS(root mean square) of Fig. 3-1 was 29.626. From the line profile of two figures the surface of a BP thin film to know that it was stable and smooth.

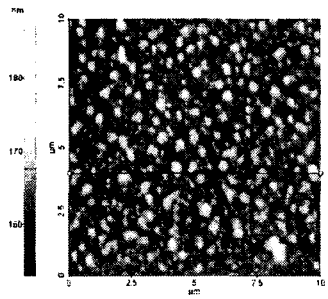

Fig. 3 AFM Result

For the Fig. 4, these diffraction peaks can know the direction of BP (1 0 1) when the diffraction range is 20 ~ 80, and it was observed near by a 2θ = 29, and a peak appears with the neighborhood in 35~ 37, 46 and 61.

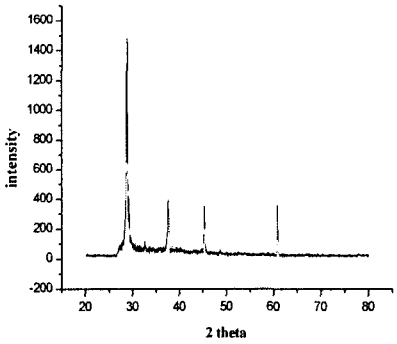

그림 4. XRD Measure result

Fig. 5 the B is with approximately 85%, and P appears with approximately 13%. It was known that the BP concentration ratio is about 13 : 2.

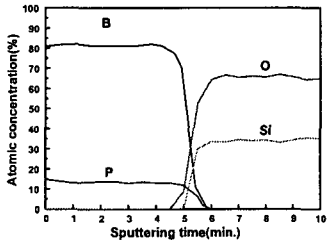

Fig. 5 AES Result

Fig. 6 are the results that measured complex permittivity of a BP thin film with temperature of 450℃ and 650℃. It looked by owning complex permittivity of approximately 5 in 1.5 ~ 2.5GHz for the deposited BP thin film at 450℃ and the deposited BP thin film looked in 650℃ by having complex permittivity of approximately 8.

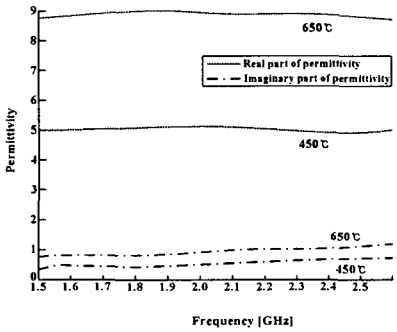

Fig. 6 Permittivity Result

4. Conclusion

In this study, we discussed the physical characteristics and microwave absorbing characteristics of BP as compound semiconductor.

We deposited BP thin film by APCVD (Atmospheric Pressure Chemical VaporDeposition), and used to 1% B_2H_6(Diborane) and 5% PH_3(Phosphine) that were diluted to H_2 as reaction gas. Carrier gas used to N_2. The substrate is used (1 1 1) Si wafer with 1.5×1.5 cm size. The deposition temperature were each 450℃ and 650℃. The optimum reaction gas rate of B_2H_6 and PH_3 were each 20 cc/min and 60 cc/min., and the

optimum carrier gas rate was 1 ℓ/min. The films were annealed each 400℃ and 550℃ during 1 hour for crystallization and stabilization in N_2 ambient.

To analyze the surface roughness and grain size of BP films grown by APCVD, the AFM was used in this study. The result of surface roughness measurement using AFM was shown that RMS(root mean square) is 29.626Å. So, we could know every commonplace thing. The XRD was used to analyze the preferential oritation and crystallinity of BP films. The measurement of XRD shows that the films have the peack 29°, 37°, 46° and 61° in reflective degree between 20°and 80°and have the preferred orientation of (1 0 1).

Also, the measurement of AES is shown the films have $B_{13}P_2$ Stoichiometry.

For the Result of microwaves absorption properties using VNA, we obtained the permittivity of BP about 8 between 1.5 ~ 2.5GHz.

In this study, we obtained the BP thin film by deposited in atmosphere pressure, and known to applicate as microwave absorbtion material of BP thin film.

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