C−4−2 Film Growth of BeO Using R-ICB Technique and Applications to Electronic Thin Film Devices

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Film growth of BeO with a high melting point of 2540°C is successfully achieved at low substrate temperatures up to 400°C using the reactive ionized-cluster beam (R-ICB) technique.[1-3] BeO crystallizes in the wurtzite structure, and is an excellent insulator with a resistivity of $\sim 10^{13}\,\Omega$cm and a high thermal conductivity of the same order as that of Al, resulting from lattice vibrations. This material is also interesting because of a high sound velocity (∿ 13 km/sec) and a high mechanical hardness (*Morse hardness 9*) and its being chemical erosionproof. In practice, however, only BeO ceramics has been used so far because of a difficulty in preparing thin films of BeO by conventional technique.

In this paper, the experimental results on thermal transport and optical properties of BeO films prepared using the R-ICB technique are described. An attempt of growing a BeO film on a Si wafer is made to offer a film coating method for large scale integrated circuits. In addition, the possibility of surface-elastic wave transducers in a GHz band is proposed on the basis of the experimental results of optical properties and sound velocity of grown BeO films.

Be cluster beam is produced by adiabatic expansion from a special nozzle, and reacted with oxygen in a partial pressure of 10^{-5}- 10^{-4} Torr after ionization by electron bombardment. BeO films were grown on glass and (0001) sapphire substrates under the deposition condition : $I_e \simeq 300$ mA (approximately 30% of the total clusters is ionized) , $V_a \simeq 0$ (with only the kinetic energies corresponding to the ejection velocities of clusters) , and $T_s \simeq 400$°C.

Transparent BeO films with the C-axis preferential orientation which is peculiar to a hexagonal structure were obtained on glass substrates. Figure 1 shows (a) an X-ray diffraction pattern and (b) SEM structure of BeO film. For using the sapphire (0001) plane, epitaxial growth of good quality BeO films was possible with only ejection velocities of Be-clusters, because of the close agreement of the lattice constant ($a \simeq 2.695$ Å) of BeO with the distance (2.742 Å) between nearest neighboring atoms

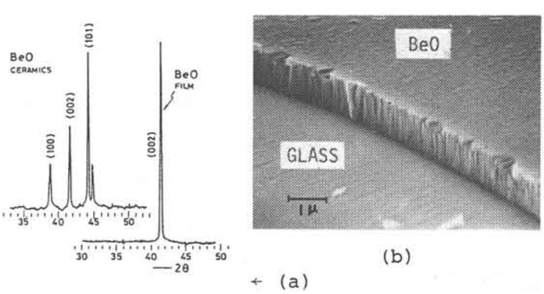

FIG.1 (a) X-ray diffraction pattern of BeO film compared with that of thermally baked BeO ceramics; (b) SEM structure of fractured edge of BeO film grown on a glass substrate.

on the sapphire (0001) plane.

Thermal transport properties of the C-axis oriented BeO thin films were investigated. From the results, anisotropic thermal conductivities parallel and perpendicular to the C-axis were determined to be $\kappa_{ph}^{//} \simeq 2.6$ w/cm deg and $\kappa_{ph}^{\perp} \simeq 0.6$ w/cm deg, which correspond to that of Al. The high lattice thermal conductivity of BeO can be attributed to the high Debye temperature ($\sim$1053K) and the high bonding energy among the constituent atoms of this material.

An attempt of growing a BeO film on a Si-(111) wafer was made. Figure 2 shows the SEM photograph of the fractured edge of an Al/BeO/Si structure, in which BeO film was deposited on Si-(111) wafer on the conditions that $I_e \simeq$ 300 mA, $V_a \simeq 0$ kV, and $T_s \simeq 400$ °C. Al film was evaporated using a conventional method. As seen in the photograph, the Si-wafer is electrically isolated from Al-layer with the highly oriented BeO layer, but thermally shorted with Al. The use of BeO film as an interface layer, therefore, is of great advantage to develop high power large scale integrated or hybrid circuits, where thermal radiation will become a serious problem in the furture. Highly oriented BeO films were also found to serve reducing the surface state density at semiconductor surface.

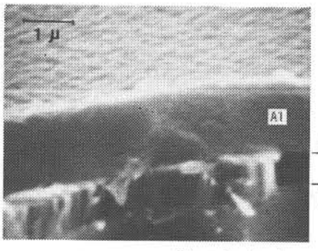

FIG.2 SEM photograph of the fractured edge of an Al/BeO/Si structure.

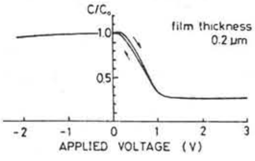

FIG.3 C-Vcharacteristics of an Au/BeO/Si MOS diode.

Figure 3 shows a C-V chracteristics of an Au/BeO/Al MOS diode measured at 100 kHz. The surface state density at Si-BeO interface Q_{ss} was about 1.6×10^{-8} c/cm^2, hence $Q_{ss}/q \simeq 1.0 \times 10^{11}$ cm^{-2} which was lower than that of Si-SiO_2 layer ($Q_{ss}/q \simeq 2.5 \times 10^{11}$cm^{-2}).

Measurements on the infrared reflectivity of BeO epitaxial films were carried out. From the results, it was found that the optical and static dielectric constants are $\varepsilon(\infty) \simeq 3.92$ and $\varepsilon(0) \simeq 6.5$, and that the sound velocity and the elastic constant parallel to the C-axis are $U_s^{//} \simeq 13.8 \times 10^3$m/sec and $C_{33}^{D} \simeq 57.9 \times 10^{10}$N/m^2, respectively. Accordingly, a wide variety of passive and active surface-elastic wave transducers in a GHz band will be possible using BeO films. The study on some of the transducers is now in progress.

Reference

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