Electrical Properties of Mo/III-V Compounds Schottky Barriers

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Because of the advent of using high power III-V MESFET devices, the need for a high reliability metallization technology becomes more crucial. The electrical characteristics of Schottky barrier contacts are generally very sensitive to the interdiffusion of constituents in the vicinity of the metal-semiconductor interface. Therefore, a preferred approach for improving the reliability of Metal-Semiconductor contacts is to utilize systems that are metallurgically non-reactive. In recent years, many transition metals are considered and investigated metallurgically as possible candidates for III-V Schottky barriers. Due to the large difference of electronegativity and thermal expansion coefficient between these metals and III-V compounds, interdiffusion, compound formation and lack of adhesion are existed. For these reasons it is interesting to find and investigate new Schottky barrier structures with near-ideal electrical properties. The early transition metal, Mo, which has the relatively small electronegativity and thermal expansion coefficient closed to that of GaAs, prompts us to prepare the Mo/III-V compounds contact and study the Schottky barrier properties of these contact systems.

The (100) III-V compound semiconductors used are n-type with the carrier concentration in the range of $5 \times 10^{16}$ to $10^{17}$ cm$^{-3}$. The 88:12 weight parts Au-Ge eutectics are evaporated and annealed for back surface ohmic contact formation. The 0.1 μm Mo is electron-beam evaporated at a rate of 3Å/sec in the background pressure less than $7 \times 10^{-7}$ torrs to reduce oxidation. After the Mo evaporation at different substrate temperature, the samples are annealed for 10 minutes in the dried N$_2$ gas and the temperatures varied from 200°C to 600°C. The electrical properties and interface of Schottky barriers are assessed by I-V, C-V, DLTS and Rutherford Backscattering (2MeV He$^+$, θ = 160°), respectively.

All the forward log I-V characteristics of as deposited Mo/III-V Schottky barrier systems are linear over five decades. The values of ideal factor are 1.03, 1.10 and 1.06 for GaAs, GaAs$_{0.8}$P$_{0.2}$ and GaAs$_{0.6}$P$_{0.4}$, respectively. And the reverse saturation current densities are in the order of $10^{-8}$ A/cm$^2$. It means the Mo/III-V Schottky barriers have the good diode performance.

The Schottky barrier height ($\Phi_{B1}$) is calculated from the extrapolation of the forward current plot to the intersection with the current axis ($J_s$) by the expression $J_s = A* T^2 \exp(-\Phi_{B1}/kT)$

where the effective Richardson constants $A*$ are the calculated values obtained from the relation

$$A^*(\text{GaAs}) = m^*(\text{GaAs})$$

$$A^*(\text{GaAs}_{1-x}P_x) = m^*(\text{GaAs}_{1-x}P_x)$$

And it is also deduced from the C-V analysis and $J_s/T^2$ vs 1/T plot for $\Phi_{B2}$, respectively. The results are shown in Fig. 1 and Fig. 2. Fig. 1 shows the $\Phi_{B2}$ vs mole fraction of GaAs$_{1-x}P_x$ and it increases linearly with the increasing of the mole fraction. This phenomenon can be attributed to the linear relation of band gap with the mole fraction of GaAs$_{1-x}P_x$ in the direct band gap. In Fig. 2 the...
the variation of $\phi_B$ with the thermal annealing temperature is presented. The barrier height deduced from C-V is larger than that deduced from I-V. This difference may be ascribed from the interface state or native oxide existed in the interface of metal-semiconductor. The heat treatment appreciably degrades the apparent barrier height about 0.2 eV after 500°C or above temperature annealing, whereas the ideal factor increases about 0.05-0.1. Such degraded values of $\phi_B$ could be interpreted as being caused by the physical irregularities at the interface as a result of interdiffusion. In order to conform this consideration, the RBS and DLTS are performed. Fig.3 shows the Rutherford backscattering spectra of 1000Å Mo on GaAs$_{0.6}$P$_{0.4}$ in the 200°C as deposited state and after 600°C annealing. It can be seen the Mo has penetrated into the GaAs$_{0.6}$P$_{0.4}$ about 16Å after the heat treatment. By the DLTS analysis, it has found and corresponds with the RBS result that the hole trap, $E_V$+1.0 eV, exists in the samples annealed above 500°C temperature. This deep level increases the generation current, so the reverse saturation current degrades about 3 orders. From the RBS and DLTS results, it can be tentatively considered that $E_V$+1.0 eV is as a Mo acceptor level in GaAs$_{0.6}$P$_{0.4}$. Further systematic studies are considering and performing.

References