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B—5—4 Low Temperature Alloyed Contact Formation in Various Metal-Semiconductor Couples

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Recent development in electronics, such as the computor technology, has mainly been relying on the progress of the semiconductor device technology. These devices function in a given system only through the connection to external electric circuits. These electrical connections are essentially ohmic contacts between metals and semiconductors(M-S). Also the M-S contacts have been investigated many years for the fabrication of good Schottky barrier devices. The reliability of a given device depends partly on the stability of the M-S contacts as ohmic contacts and Schottky barriers. In order to produce reliable electronic devices, we must have microscopic knowledge about the M-S interfaces. In the present study, interfaces of several M-S systems were examined by the Auger electron spectroscopy with the aid of Ar^+ ion sputtering technique. To our surprise, it was found that some groups of semiconductors reacted with metals at the interfaces even at room temperature, for example at the Si(substrate)-Au(film) interface.[1]

[Experiments and Discussions] Semiconductor wafers were cleaned by the flash heating method in the vacuum($\sim 10^{-10}$Torr) or by the Ar^+ ion sputtering followed by the deposition of metal(Au, Cu, Pd, etc.) films on thus cleaned semiconductor surfaces. Figure 1 shows the experimental result for the Cu-InP specimen; the depth profile of the specimen was obtained by Ar^+ ion sputtering technique. As is shown in Fig.1, coexistence of Cu atoms with In and P atoms were found in the interface region with thickness of around several hundreds Å to indicate that the interface was alloyed as seen in the case of Si-Au system. This low temperature alloy formation at the Cu-InP interface is evidenced by the chemical shift of P(LVV) Auger

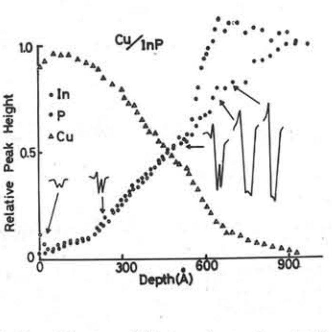

Fig.1 Depth profile of a Cu-InP specimen. P(LVV) Auger spectra are also shown.

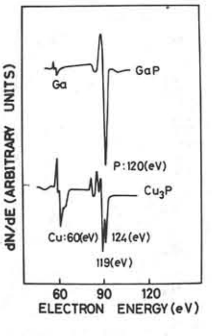

Fig.2 P(LVV) Auger spectra from P in semiconductor GaP and from P in metallic compound Cu_3P.

spectra at the interface region which is also observed in the compound of Cu_3P (Fig.2). Similar phenomena, the low temperature alloy formation at M-S interface, were observed in metal-Ge, -GaAs, -InSb and -Si systems. On the contrary, such a phenomenon was not observed for wide gap semiconductors(or insulators)-metal couples, such as metal-SiO_2, -SiC and-NaCl. These results are summarized in Table 1, where dielectric constants(ε) of semiconductors are also shown. From the already published studies on Schottky barrier heights, semiconductors have been classified roughly into two groups whether the barrier height, ϕ_B, is dependent on metal or not; S≅1 or 0 in the relation of $\phi_B = S\phi_M$+const., respectively, where ϕ_M is the work function of a metal. The former case, S≅1, is explained by the simple relation by Schottky. And the latter case, S≅0, has been understood in terms of the concept of Bardeen's surface states, and therefore such barrier is sometimes called as 'Bardeen barrier'. According to Kurtin et al,[2] the materials with S≅1 and S≅0 correspond to "ionic" and "covalent" semiconductors, respectively. In this respect, Phillips, using already available experimental data, plotted 1-S against ε-1 for the theoretical consideration and concluded that the transformation from "ionic" to "covalent" behavior occurs at $\varepsilon_c \cong 7$, where ε_c is called as critical dielectric constant.[3] Regarding to this value of ε_c, our result(Table 1) claim almost the same critical value of ε for semiconductors to react with metals at room temperature, namely $\varepsilon \gtrsim 8$, which corresponds to the "covalent" case, and the interfaces of the semiconductor-metal systems are diffuse or alloyed. Therefore, our present result strongly suggests that some other explanations rather than that by Bardeen's surface states must be considered as attempted by Inkson and Anderson[4] and Spicer and Brillson[5] to understand the metal-independent nature of potential barriers, because Bardeen assumed no reaction at the interfaces or sharp interfaces instead of alloyed ones.

Table 1

Semiconductor	Interface	Dielectric Constant
Ge	alloyed	16
InSb	alloyed	15.2
Si	alloyed	12
GaAs	alloyed	10.5
InP	alloyed	9.5
GaP	alloyed	8.4
SiC	sharp	6.4
SiO_2	sharp	3.5
NaCl	sharp	2.5

References

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