Annealing Ambient Influence on Holding Time Characteristics of $^{75}\text{As}^+$ -Implanted MOSFET's

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Implantation of arsenic ions is an effective technique for formation of shallow source and drain junction in short channel MOSIC's, because of smaller diffusion coefficient than phosphorus even at high temperatures, and high controllability¹⁾. Leakage current of arsenic-implanted junction has already been measured, and it is reported that a minimum annealing temperature of 900°C is required to produce low-leakage junction, which is comparable to conventional phosphorus diffused junction²⁾. Refresh time of dynamic MOS RAM fabricated by using arsenic ion implantation has also been measured, and the mean refresh time of 150 msec at 75°C has been obtained³⁾. These results indicate that arsenic ion implantation might be adaptable to MOSIC's fabrication. Post-implantation annealings in all the above investigations, however, were carried out in nitrogen atmosphere. It is often required that annealing is carried out in oxidizing atmosphere to grow passivating oxide layer simultaneously, to prevent short circuit or to reduce parasitic capacitance between implanted layer and metallization. However there have been few experimental data reported on junction characteristics of $^{75}\text{As}^+$ -implanted layers annealed in oxidizing atmosphere. In this note, we report the results of holding time characteristics of $^{75}\text{As}^+$ -implanted MOSFET's annealed in oxidizing atmosphere, since they are very important for application to dynamic MOSRAM's.

The n -channel Si-gate MOSFET's were fabricated on $1.4\Omega\text{-cm}$, p -type Si wafers. The processes were the same as those conventionally used in the fabrication of short channel Si-gate MOS transistors, except that thermal

phosphorus diffusion into source and drain regions was replaced by arsenic ion implantation. The $^{75}\text{As}^+$ ions of $5 \times 10^{15}/\text{cm}^2$ were implanted through 400 Å-thick oxide with a 100 keV accelerating energy into source and drain regions. Subsequent annealings were performed at 1000°C in the ambients of nitrogen, dry oxygen and steam for 30 minutes. Increase in thickness of the oxide layer after annealing was less than 500 Å in the case of dry oxygen ambient. On the other hand, 0.4 μm-thick oxide was grown after annealing in steam. Junction depth was 0.3 μm in cases of nitrogen and dry oxygen ambients, and 0.25 μm in the case of steam ambient. Correspondingly, sheet resistance was 40 Ω/□ in first two cases, and 45 Ω/□ in the third case. For comparison, phosphorus diffused samples of 0.5 μm junction depth were also fabricated.

A circuit used for the measurement of holding time is shown in Fig. 1 (a). A single pulse ϕ_G of 1 msec, 8 V was applied to the transfer gate terminal, and the input pulse V_{in} of 2 msec, 8 V was on. The holding time is defined by the time when the total stored charges are released to the surrounding area from the storage region shown by thick line in Fig. 1 (a). The stored charges may be discharged through junction leakage and gate oxide leakage. The leakage current through oxide is usually a few orders of magnitude smaller than the junction leakage current, and its effect can be neglected. The typical holding time characteristic is shown in Fig. 1 (b). The curve indicates time decay of the output voltage. The output voltage increases gradually due to release of stored charge, which is caused by recombination current of the holding junction, and then abruptly goes up to V_{DD} due to the increase of substrate current which flows in the sense transistor⁴⁾.

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Fig. 1 Diagram of the circuit used for measurement of holding time characteristics (a), and typical example of holding time characteristics (b)

Fig. 2 Holding times measured on $^{75}\text{As}^+$ -implanted samples annealed in various ambients. For comparison, values for phosphorus diffused samples are also shown

Holding times of samples annealed in various ambients of nitrogen, dry oxygen and steam at 1000°C for 30 minutes after the implantation are shown in Fig. 2. The holding times of the samples annealed in the nitrogen ambient are comparable to those for the phosphorus diffused samples. This result is consistent with the previously reported results^{2,3}. The amount of the charge Q stored in the region indicated by thick line in Fig. 1 (a) is approximated by $Q \approx C \cdot (V_{in} - V_T)$, where C is the gate oxide capacitance of the sense transistor. In the present case, the gate oxide thickness is $400 \text{ \AA}$, and C becomes 0.27 pF (gate area is $320 \mu\text{m}^2$). The stored charge Q becomes $1.8 \times 10^{-12} \text{ coulomb}$. Hence, the average leakage current density through the holding junction ($I_{\text{leak}} \approx Q/\tau$) is about $7 \times 10^{-16} \text{ A}/\mu\text{m}^2$ (junction area is $45 \mu\text{m}^2$). This value is low enough, and comparable to that of conventional phosphorus diffused junction. The holding times of samples annealed in steam are the shortest. This can be considered due to the fact that dislocation loops or dislocation networks are generated during the anneal, and possible metal impurities, which become recombination centers, precipitate into these loops or networks, as revealed by TEM observation by Akasaka and Tsukamoto⁵. In the present measurement, the holding times of samples, annealed in dry oxygen ambient, are comparable to those for phosphorus diffused samples. We consider that the number of dislocation loop or dislocation network is not enough to degrade the junction characteristics after annealed in dry oxygen, when the implantation is performed through SiO_2 layers. Tsukamoto *et al.* also reported that junction breakdown characteristics are not so much degraded in the case of dry oxygen ambient as in the case of steam ambient⁶.

In conclusion, the holding time characteristics of $^{75}\text{As}^+$ -implanted MOSFET's have been measured. Holding times of the samples annealed in ambients of nitrogen and dry oxygen at 1000°C for 30 minutes are comparable to those for phosphorus diffused samples. It has been found that annealing in steam ambient considerably degrades holding time characteristics.

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協会レポート

第2回工業電解用電極材料技術懇談会

上記第2回の研究会が5月10日(木)午後横浜国立大学エネルギー材料研究施設で開かれた。約40名の方々が参加された。

当日のプログラムの最初は、金属材料技術研究所の藤井哲雄、小玉俊明両氏の研究で、「プラズマジェット溶射法被覆チタン電極の開発について」であった。小玉氏が講演された。

ニッケルフェライト、コバルトフェライト、マグネタイト、を合成したのち、プラズマ溶射でチタン基板の上に吹付け、フェライトのもつ電極触媒能と金属チタンの電極基板としての特性とを組合せた複合材料電極を作成することが狙いである。

食塩水を電解したときのアノードガスの分析結果、フェライトの溶解性試験、分極特性、などの結果をもとに活発な討論が行なわれた。ウスタイトの生成などを含めた溶射時の熱分解、フェライトの溶解損耗および優先溶解の有無、基板チタンの不動態化に伴う活性低下などが話題となった。

次に中川防蝕工業(株)の福谷英二氏から「電気防食

用難溶性電極の現状と将来」について防食技術[27, 583 (1978)]に発表された解説を資料として紹介があった。黒鉛系電極はわが国ではあまり用いられていないが海水中の使用には最適である。高ケイ素鋳鉄系電極は土中、淡水中の使用に適している。磁性酸化鉄電極は主として土中電極として用いられる。フェライト系電極は小型施設の電気防食が対象となる。鉛系電極は塩素イオンのある環境で、抵抗率の低い場合に消耗量が少なく、海水中の電極として圧倒的に多く使用される。白金系電極はほとんどすべての環境で使用可能である。RuO₂被覆のDSAは白金系電極の代用として今後用途が増加するであろう。

討論では福谷氏の長年にわたる使用経験にもとづいた含蓄のある話を伺うことができた。たとえば電極系全体としての寿命を支配するのは電極本体の寿命ではなく、結線部の断線事故である場合が多い。

討論のあとは高橋懇談会主査を囲んでの懇親会が開かれ参加者の意見の交流を一層深いものとした。第3回の会合は7月26日(木)午後同じく横浜国立大学エネルギー材料施設(弘明寺)で開かれる(電気化学4月号p. 297 会告参照)。

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