NOTE

PROCESS AND MATERIAL PROPERTIES OF WSI, FORMED BY DISCHARGE TREATMENT

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INTRODUCTION

Tungsten and its silicide are the preferred gate and interconnection materials in MOS circuits. It is because they improve the device speed as the device size is reduced below a micros. In order to make reliable silicides of tungsten, it is essential to have silicides formed either by codeposition of metal and silicon followed by high temperature annealing[1].

Fig. 1(a,b). Caption opposite.
or through contact reaction between a metal and silicon. The latter is generally used in a self-aligned silicide-gate process. In this case, the presence of small amounts of impurities, mainly oxygen, can hinder the reaction and result in formation of blisters and voids in thin-film overlays [2]. There are various methods to eliminate the problem such as (i) using a UHV system; (ii) substrate heating during deposition [3-5]; and (iii) ion beam mixing [6]. These are not feasible for device fabrication. In this study, the tungsten silicide has been successfully produced by employing discharge treatment of the W-Si system. The process and material properties both electrical and structural are discussed here.

RESULTS AND DISCUSSION

Figure 1 shows the X-ray diffractograms of the as-deposited (a), vacuum annealed at 630°C (b) and 910°C (c). The tungsten film appears to be free from impurity. After low-temperature anneal, there appears to be no trace of silicide formation. The increase in vacuum anneal temperature causes the change in the tungsten film grain size only, as evidenced by the sharp peaks in the diffractograms. The silicidation remains suppressed due to presence of impurities. The films also peel off in general when subjected to the "cello" tape adhesion test and ultrasonic cleaning in acetone for 5 min. The discharge treatment of the as-deposited tungsten film by the method outlined above prior to vacuum anneal induces silicidation [7]. We believe that this is because the discharge treatment disperses the impurity and induces the mixing of tungsten and silicon. The film is found to be amorphous [Fig. 2(a)]. The subsequent vacuum anneal at 500, 700, 800 and 1000°C for 30 min converts the layers into hexagonal WSi2, a mixture of hexagonal and tetragonal phases of WSi2 and finally into tetragonal WSi2, respectively as shown in Fig. 3(b-e). It is obvious that WSi2(T) is the end and stable phase and is formed only at higher temperatures.

These results are found to be similar to those of CVD tungsten silicide reported by Saraswat et al. [9] and thus suggests an alternate method for growing similar WSi2 films. The sheet resistance of WSi2 so formed increased up to 650°C and decreased thereafter as shown in Fig. 3. These results are similar to those obtained with annealed samples of W-Si [10]. However, W3Si is absent in this case. The minimum sheet resistance was of the order of 6 Ω/□ and was uniform across the wafer. This is what was observed with a large number of samples so processed. The phase was always tetragonal WSi2. The
adherence was also excellent after 5 min ultrasonic cleaning in acetone.

CONCLUSION

The as-deposited tungsten films were not observed to react with silicon wafers or to form silicides when vacuum annealed in a vacuum furnace at high temperature. However, an effective WSi$_2$ deposit with tetragonal phase and low sheet resistance was formed when the system was subjected to a suitable discharge treatment followed by vacuum annealing in a vacuum furnace at high temperature. Thus this study provides a method for successful formation of WSi$_2$ (T).

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REFERENCES