Ta-N 스트레인 게이지의 제작과 그 특성

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Fabrication of tantalum nitride thin film strain gauges and its characteristics

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Abstract: This paper presents the characteristics of Ta-N thin film strain gauges that are suitable for harsh environemts, which were deposited on thermally oxidized Si substrates by DC reactive magnetronsputtering in an argon-nitrogen atmosphere (Ar-N_2 (4 ~ 16 %)). These films were annealed for 1 hr in 2×10^{-6} Torr in a vacuum furnace with temperatures that ranged from 500 - 1000°C. The optimized deposition and annealing conditions of the Ta-N thin film strain gauges were determined using 8 % N_2 gas flow ratio and annealing at 900°C for 1 hr. Under optimum formation conditions, the Ta-N thin film strain gauges obtained a high electrical resistivity, ρ = 768.93 μΩ · cm, a low temperature coefficient of resistance, TCR = -84 ppm/°C and a high temporal stability with a good longitudinal gauge factor, GF = 4.12. The fabricated Ta-N thin film strain gauges are expected to be used inmicromachined pressure sensors and load cells that are operable under harsh environments.

Key words: Ta-N thin film, Strain gauge, TCR, GF, Harsh environments

1. Introduction

Recently, the demand has increased in many industrial fields for non-intrusive pressure and load measurements in environments of high temperature, humidity and vibration. Such applications include pressure, load and vibration instruments in automotive, aircraft-engines, materials processing industries, medical instruments and industrial control systems [1].

Generally, ceramic thin film strain gauges for pressure and load instrumentsdiffer from conventional foil gauges. The metal thin film strain gauges have no creep and a highstability because they do not need adhesives. Moreover, they may be mass produced at a low cost using current thin film technologies. Also, the large surface-to-volume ratio of the sensing film increases the dissipation heat that resultsfrom self-induced heating [2]. The strain gauges can be used inhigh temperatures because of thermal comprehension. In comparison with the other metals, several ceramics have comparatively high electrical resistance, high stress sensitivity and a high GF [3].

The aim of this work was to evaluate Ta-N thin films as high temperature strain gauges. The Ta-N thin films were deposited by DC reactive magnetron sputtering in an argon-nitrogen atmosphere (Ar-N_2 (4 ~ 20 %)) on thermally oxidized Si substrates. In addition, deposition parameters and post-deposition thermal treatments were chosen for optimum formation conditions in order to improve the piezoresistive properties as the sensing element. The thin film deposition and fabrication methods for the development of piezoresistive Ta-N thin films are also presented. In addition, under optimum conditions of deposition and annealing, the thermal stability of these films was also analyzed based on the measurements from the TCR (temperature coefficient of resistance), the I (current)/ V (voltage)/ T (time) curves and hysteresis characteristics when conditions such as temperature and resistance changed. Finally, an aging effect of the Ta-N thin film stain gauges was also characterized.

2. Experiment

Ta-N thin films were deposited on thermally oxidized Si substrates by DC reactive magnetron sputtering in an argon-nitrogen atmosphere (Ar-N_2 (4 ~ 16 %)). Ta-N thin-film resistors that were 35-㎛-wide and with a 32-mm-long meandering path, were patterned using photolithographic techniques. An automatic data-acquisition system controlled by a personal computer was used for the TCR measurements in temperature ranging from 25 ~ 1000℃. Accelerated life tests at 200℃ were made to evaluate the long-term stability of the Ta-N thin-film strain gauges. I/V/T characteristics were used to analyze the electrical conduction mechanisms of the Ta-N thin-films. The hysteresis effect due to strain cycling was also examined.

3. Results and discussion

Fig. 1 shows the hysteresis characteristics of variation in the rate of resistance according to the changes in the temperature of the Ta-N thin film strain gauges as the temperature ranged of 25 ~ 150℃. The N_2 flow rate was 8 % and the annealing took place at temperature of 600℃ for 1 hr. Fig. 1 shows a nonlinearity and a hysteresis of less than 1.65 % full scale and 2.27 % full scale, respectively. The TCR values showed high linearity and low hysteresis under these conditions. The variation rate of resistance according to the temperature was very linear and its characteristics seemed to become more stable with annealing.

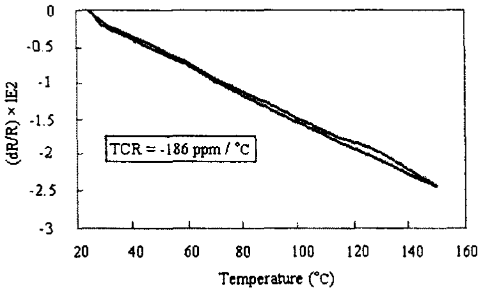

Fig. 1. The variation rate of the electrical resistance according to the temperature of the Ta-N thin-film strain gauges (N_2 flow rate : 8 %, annealing condition : 600℃, 1 hr).

Fig. 2 shows the variations of a longitudinal GF of the Ta-N thin film strain gauges with respect to the N_2 gas flow ratio. It is shown that the GF increased from 3.41 up to 6.24 as the N_2 gas flow increased from 4 to 12 %. When N_2 gas flow ratio was increased, the GF of Ta-N thin film strain gauges also increased. Despite the fact that the GF of the Ta-N thin film strain gauges in a 12% N_2 gas flow ratio was the maximum value, other experiments performed were based on an ambient 8 % N_2 gas flow ratio because of unreliable TCR variation in the 12 % N_2 gas flow ratio. It can be observed that the GF was around 4.23 without annealing, but the GF dramatically decreased when the annealing temperature of the Ta-N thin film strain gauges increased.

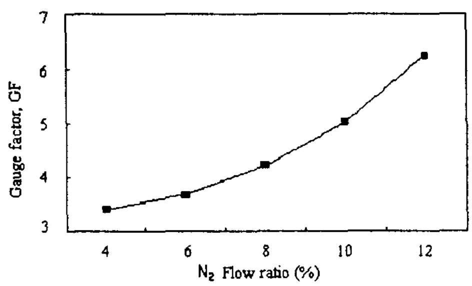

Fig. 2. Variations of the gauge factor of the Ta-N thin film strain gauges according to the N_2 gas flow ratio.

Fig. 2 shows the characteristics responses of a longitudinal stress of the Ta-N thin film strain gauges, which had an 8 % N_2 gas flow ratio and were annealed at of 900°C for 1 hr. Under optimum depositions and annealing conditions, the Ta-N thin film strain gauges changed by various factors of resistance almost linearly according to the external stress supplied. A good linearity, <3.57 %FS, in the GF behavior was observed in Fig. 2 and no appreciable hysteresis, <1 %, was detected. This value was slightly higher than the theoretical predictions for a piezoresistive metallic thin-film. A high linearity in the piezoresistive behavior was observed. These characteristics are suitable in a pressure sensing element. Under optimum deposition and annealing conditions, the variation rates of resistance of the Ta-N thin film strain gauges changed almost linearly according to the external stress supplied.

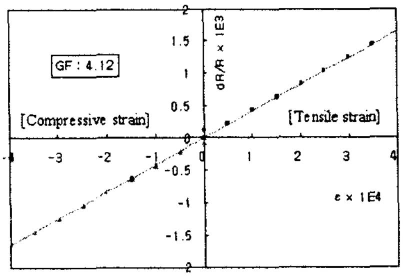

Fig. 3. The relative electrical resistance change in the Ta-N thin film strain gauges according to the longitudinal strain (N_2 gas flow ratio: 8 %, annealing condition: 900°C, 1 hr).

4. Conclusions

This paper presents the characteristics of Ta-N thin film strain gauges for high temperature applications. The optimized formation conditions of the Ta-N thin film strain gauges were determined to be annealing at a temperature of 900°C for 1 hr in an 8 % N_2 gas flow ratio. Under these optimum conditions, the Ta-N thin films for strain gauges obtained a high resistivity, ρ = 768.93 μΩ · cm, a low temperature coefficient of resistance, TCR = -84 ppm/°C and a high. temporal stability with a good longitudinal GF = 4.12. Therefore, it is expected that these Ta-N thin film strain gauges can be used in micromachined pressure sensors and load cells suitable for harsh environments.

References

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