Formation of Mo-Silicide on Mo Tip

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Abstract

This paper describes a formation of the Mo-silicide on Mo tip to compare the emission characteristics of the Mo tip. Cone-shaped Mo tip arrays were fabricated and silicidized by evaporating a 15nm-thick a-Si film on Mo tip arrays and annealing it in inert ambient at the temperature of 1000 ℃ for 60 sec. The Mo_5Si_3 phase of Mo-silicide was observed through X-ray diffraction (XRD) analysis. Although the gate voltage of the Mo-silicide tip increased by 38 V to obtain the current level of 20 nA/tip, the dependence of emission current on vacuum level was improved.

I. Introduction

Field emitter has been investigated for various applications including flat panel display, microwave amplifier, and field ionizer. Spindt-type Mo emitters are commonly used for their applications. However, there are some problems still remained such as the fluctuations of emission current due to reaction with contaminants and the decrease of emission current due to tip surface oxidation. The approaches to solve these problems have mainly focused on low workfunction material coating like DLC or Hf coating[1].

In the recent study of silicon tip, silicide was applied on the silicon tip to overcome the low electrical and thermal conductivity and poor stability of the silicon tip. The remarkable improvement of electrical characteristics was achieved[2]. Mo-silicide have lower workfunction and more resistant surface to reaction with contaminants around tip than Mo[3]. As one of the solution to overcome the problems of Mo tip, we propose the Mo-silicide formation on Mo tip. Thus, if the silicide is applied to Mo tip, it is expected that the stability of emission characteristics of Mo tip can be improved.

II. Experimentals

An experiment was executed to examine a condition of silicide formation. A 15 nm-thick a-Si film was evaporated on thick Mo film. Then, rapid thermal annealing (RTA) was performed in N_2 ambient at the temperature of 1000 ℃ for 60 sec. To evaluate the formation of the Mo-silicide, the samples were analyzed through XRD and atomic force microscope (AFM). The Mo_5Si_3 phase of Mo-silicide was observed as shown in the XRD spectra of Fig. 1. The reason on the formation of Mo_5Si_3, not $MoSi_2$, is due to the annealing condition, that is, too high temperature and the lack of Si. It can be overcome by relatively low annealing temperature below 500 ℃ and thick a-Si film[4]. The more experiment to obtain optimum condition is needed for the formation of the $MoSi_2$. AFM photographs of the surfaces of the samples are shown in Fig. 2. The rms roughness before and after annealing was 22.4 Å and 47.5 Å, respectively.

Cone-shaped Mo tip arrays using local oxidation silicon (LOCOS) process were fabricated to evaluate the electrical characteristics[5]. Fig. 3 shows the fabricated Mo tip. The Mo-silicide tip arrays were prepared by evaporating a 15nm-thick a-Si film on Mo tip arrays and annealing it in N_2 ambient at the temperature of 1000 ℃ for 60 sec.

III. Electrical Characteristics

Electrical measurements of the device were performed in an ultra vacuum chamber at the base pressure of 6.6×10^{-9} Torr. The distance between anode electrode and gate electrode was 3 ㎜. During the measurements, the cathode was grounded, the anode was biased at 300 V, and a positive DC bias was applied to the gate.

Fig. 4 shows the I-V characteristics of Mo and Mo-silicide tip array that is composed of 625 tips. For the Mo tip array, the turn-on voltage was 48 V and the gate bias of 64 V was needed to acquire the anode current of 20 nA/tip. In the case of the Mo-silicide tip arrays, those were 70 V and 102 V, respectively. The higher turn-on voltage of the Mo-silicide tip is somewhat contradictory to the result deduced by lower work function. We don't know yet why it is. The more studies on the effective workfunction of Mo_5Si_3 and the change of tip shape during the annealing are required.

Fig. 5 shows the short-term fluctuation of emission current of Mo and Mo silicide tip array. The emission current of the Mo tip array was increased by about 10 ㎂ during the first measurement. At the second measurement, the emission current was still increase. The increase of emission current for the Mo tip array can be explained well by the desorption of adsorbed contaminants[5]. In the case of the Mo-silicide tip array, owing to surface inertness of the Mo-silicide, the emission current was sustained as the same level.

The emission current change depending on vacuum level is shown in Fig. 6. The initial vacuum level of the test chamber was maintained at the pressure of 6.7×10^{-9} Torr. The pressure level increased up to 2.0×10^{-6} Torr after 15 minutes. The emission current of Mo tip decreased rapidly from 58 ㎂ to 15 ㎂, about one fourth of the starting level, while that of the Mo-silicide tip decreased from 12 ㎂ to 6 ㎂, a half. These figures illustrate that the Mo-silicide tip is less sensitive to contaminants around tip.

IV. Conclusions

Mo-silicide tip arrays were fabricated by evaporating a-Si layer on the Mo tip arrays and annealing it in N_2 ambient at the temperature of 1000 ℃ for 60 sec. Mo-silicide, Mo_5Si_3 was observed by XRD measurement.

The turn on voltage of the Mo silicide tip was higher than that of the Mo tip to obtain the same emission current. However, in the experiments on short term fluctuation and vacuum level dependency of emission current, the Mo-silicide tip was more stable and less dependent on vacuum level than that of the Mo tip. It is due to the surface inertness of Mo-silicide. More works are needed to obtain $MoSi_2$ instead of the Mo_5Si_3.

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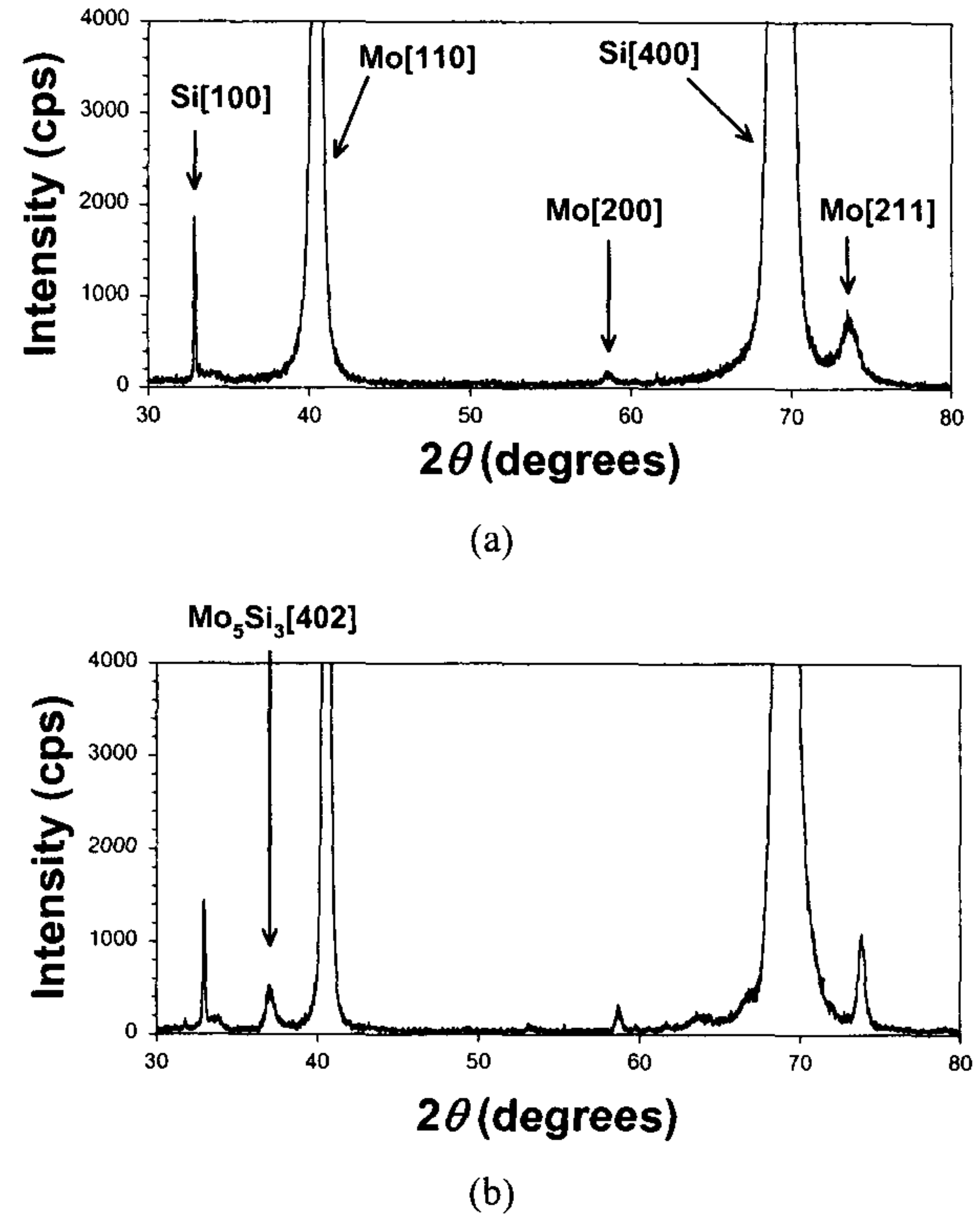
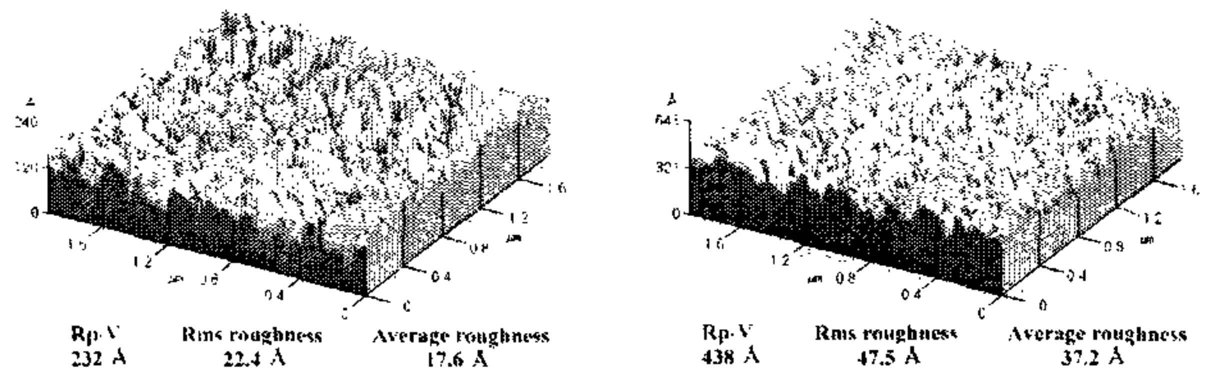


(a)

(b)

Fig. 1. The X-ray diffraction spectrum for a-Si film (15nm) on Mo substrate (a) before and (b) after annealing at the temperature of 1000 ℃ for 60 sec, respectively.



(a) (b)

Fig. 2. The surface morphology (a) before and (b) after annealing observed by atomic force microscope.

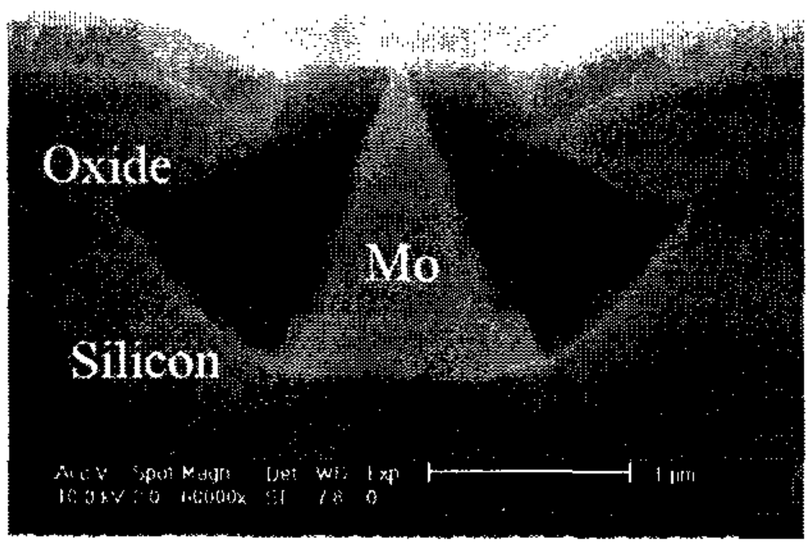


Fig. 3. The cross-sectional SEM image of Mo tip.

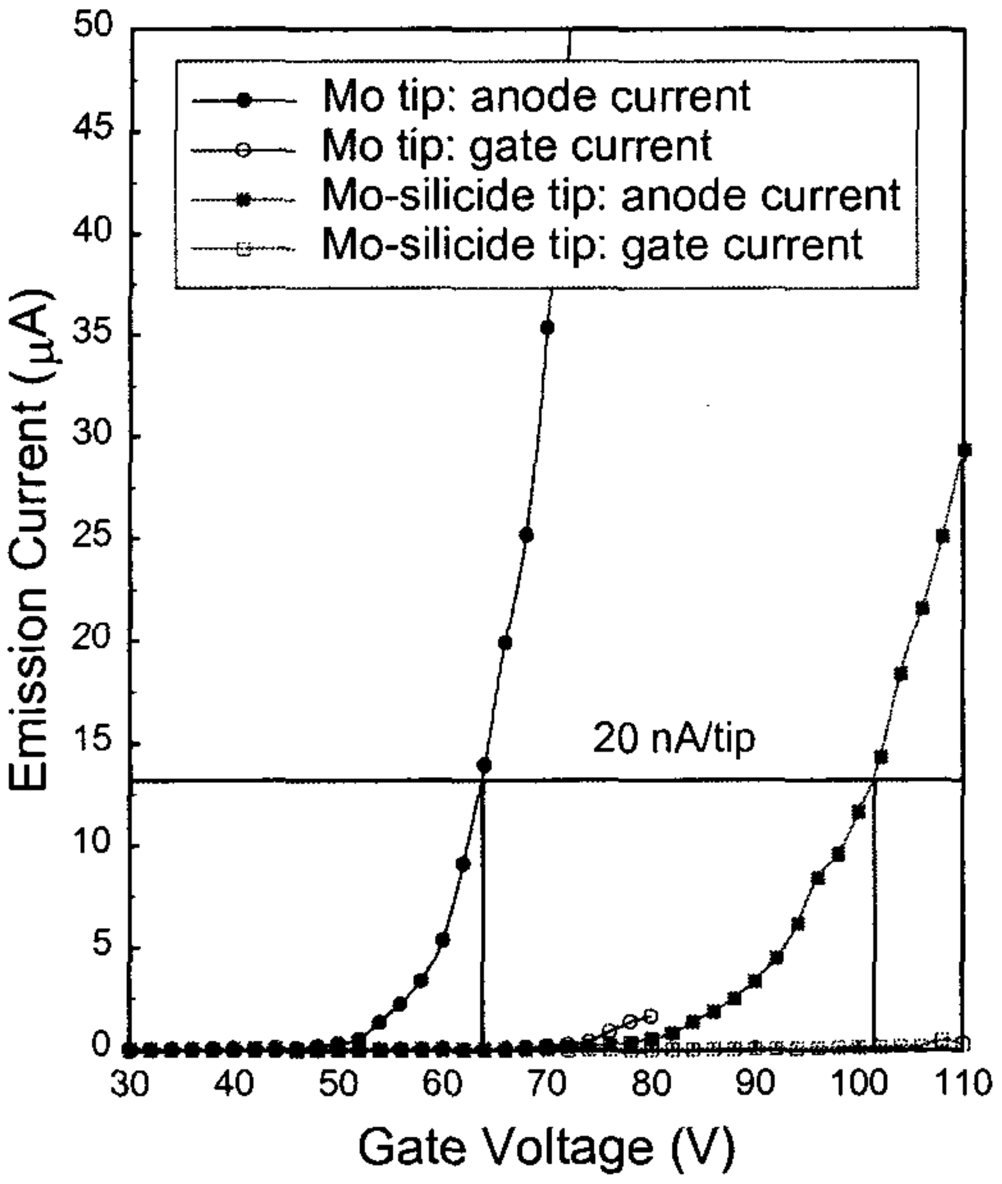


Fig. 4. The I-V characteristics of Mo and Mo silicide tip arrays.

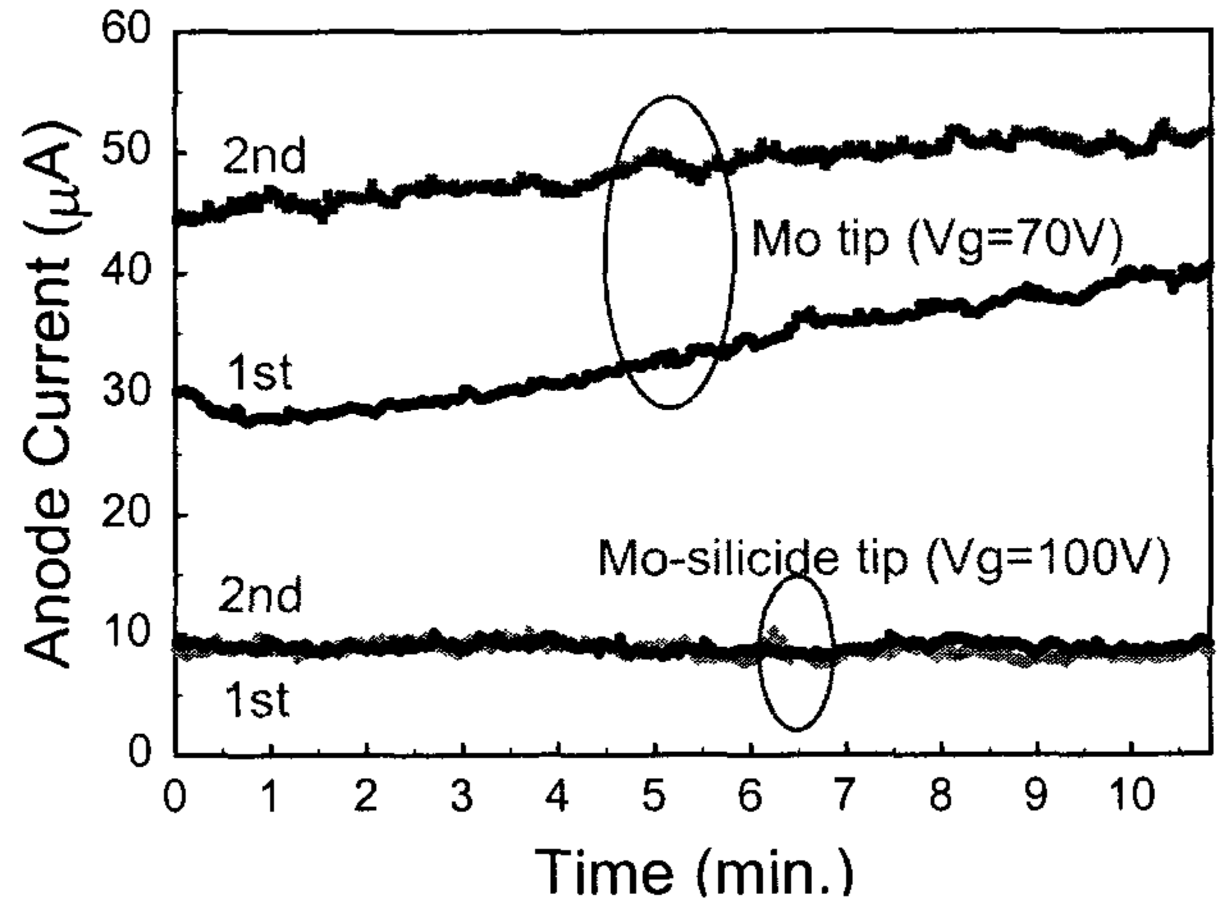


Fig. 5. The emission current fluctuation of Mo and Mo-silicide tip arrays.

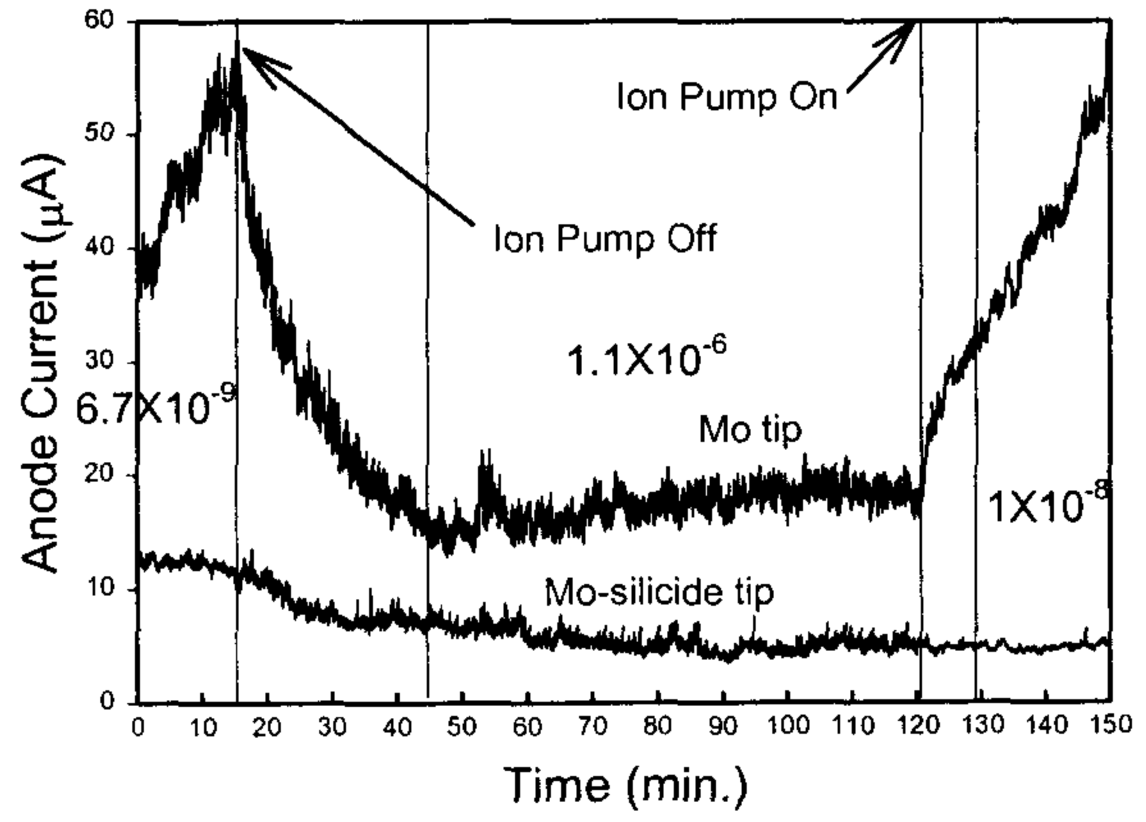


Fig. 6. The emission current changes depending on vacuum level.