Formation of an Aluminum Parting Layer in the Fabrication of Field Emitter Arrays Using Reflow Method

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Abstracts

We propose a new method for the formation of an aluminum parting layer in the fabrication of field emitter arrays, in which we used a reflow property of aluminum at a lower temperature than the deformation point of glass. After the sputtered aluminum layer on the gate metal was etched for the formation of gate holes, we carried out a rapid thermal annealing process, by which the aluminum slightly diffused into the gate hole. This reflowed aluminum could be used as a parting layer and emitter arrays were easily fabricated using this method.

Introduction

Field emission display (FED) is a promising flat panel display for the next generation. For the efficient electron emission at a low voltage, a conical tip has been used as a field emitter. The first reliable tip shape was presented by Spindt [1], who used an electron beam evaporator. The equipment has a characteristic property different from others, that is, the directionality of deposition. For the fabrication of the conical tip, what is called a Spindt-type tip, the electron beam evaporator is used for two layers; one is an aluminum parting layer, the other is the layer for tips. In depositing the tip layer, substrates are perpendicular to the incident beam of the tip material, in general, molybdenum. On the other hand, substrates are of about 15 degree to the incident aluminum beam. The grazing-angle deposition of aluminum can make the size of the gate hole reduce and especially, since the aluminum is not deposited on the bottom of the hole, the layer on the parting one except for tips can be lift-off.

However, the fabrication method of tip arrays by using the electron beam evaporator is not adequate for large area displays, because the larger the area of the display, the longer the distance from a source to a substrate and the bigger the size of the equipment is. Especially, in case of the deposition of the parting layer, we need a rotational deposition of aluminum with a grazing angle and the equipment must be very large in size and is difficult to make.

In this article, we proposed a new method for the formation of an aluminum parting layer using a sputter deposition and a reflow process of aluminum, instead of a grazing angle deposition using an electron beam evaporator.

Experimental Procedures

Figure 1 shows our new method for the fabrication of a metal tips compared with the conventional Spindt-type field emitter tip. A gate metal and a gate dielectric were deposited on a cathode layer like the usual method. The gate dielectric and the gate metal were plasma-enhanced silicon oxide and TiW, respectively. In the conventional procedure for Spindt-type field emitter tips, gate holes are formed after these processes, but in our method, an aluminum layer (3000Å, including 1% Si) was deposited on the gate metal without the formation of gate holes (1 ㎛), which were formed by plasma etching.

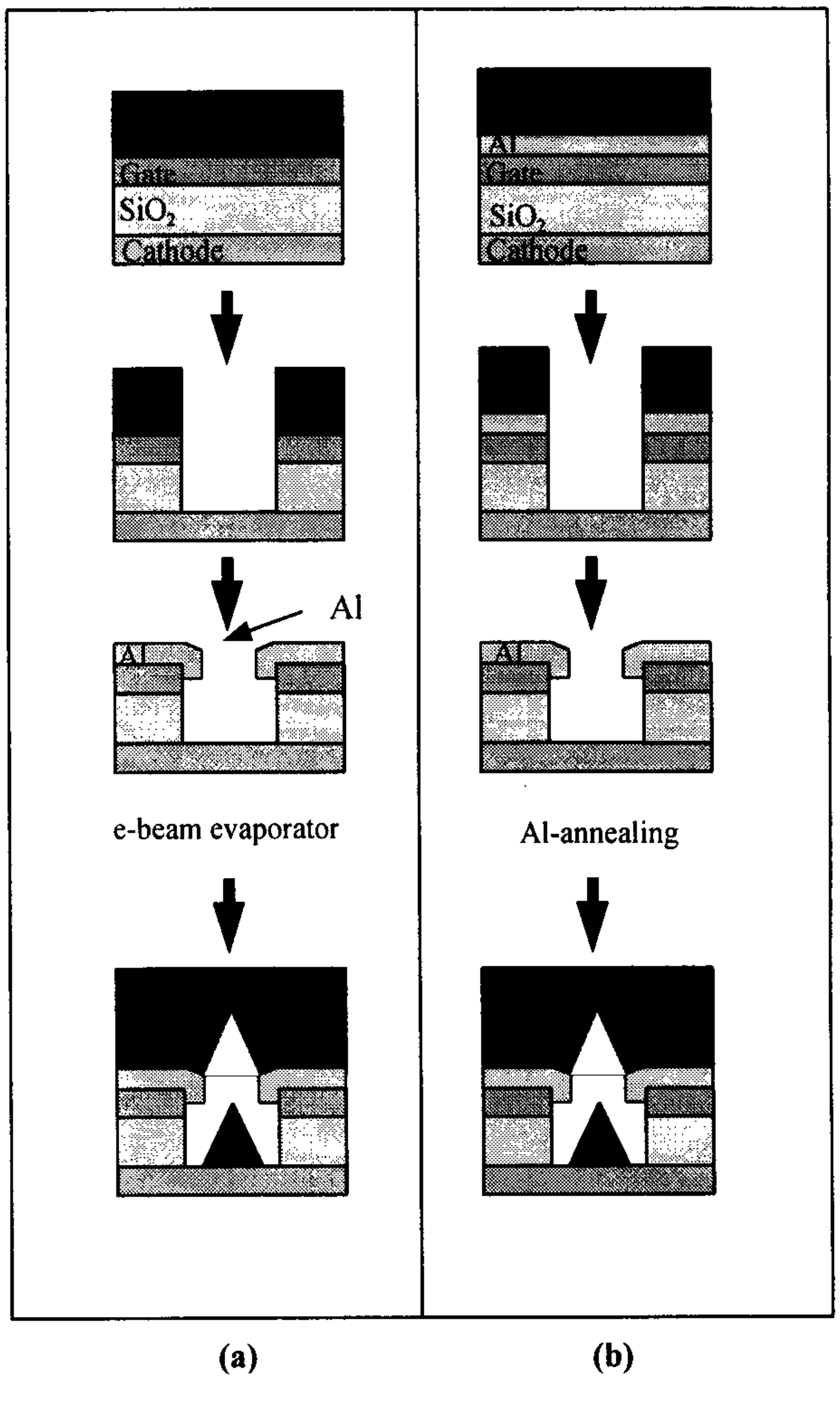


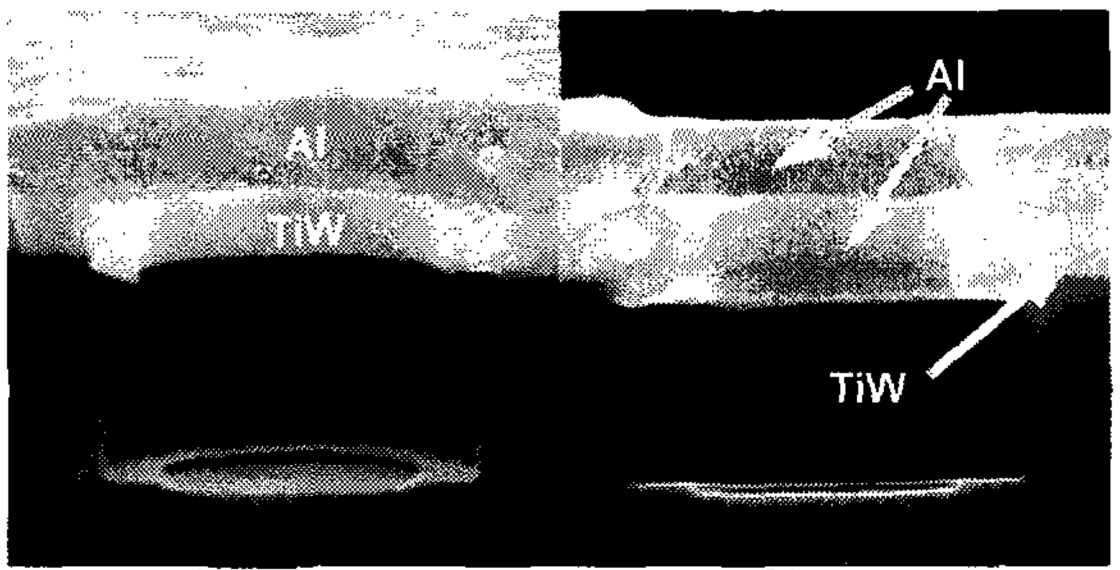
Fig 1. (a) Conventional fabrication procedure for "Spindt-type" emitter tips, (b) a new method for the formation of metal tips by using Al-reflow.

To obtain the same shape with a conventional parting layer, we carried out a rapid thermal annealing at a lower temperature (= 480 ℃) than a temperature (~ 550 ℃) used for the Al reflow process, which is widely used in contact hole refill step in the fabrication of DRAM . In case of the Spindt-type tips, an aluminum layer is deposited at a grazing angle using an electron beam evaporator. For the formation of tips, molybdenum was deposited by an electron-beam evaporator, and as a result, we obtained a cone-like tip.

Results and Discussion

Figure 2 shows SEM (scanning electron microscope) photographs of a non-annealed and an annealed (at 480℃) samples in which gate holes were formed by plasma etching. The aluminum layer was deposited on the TiW gate metal layer, and then we etched the three layers – Al, TiW(gate metal), and SiO_2(gate dielectric) - with the same PR hole pattern. For the Al reflow process, we carried out a rapid thermal annealing process in an ambient of N_2. The process temperature and time of this process were 480℃ and 60sec, respectively. The temperature, 480℃, is lower than that of the deformation temperature of sodalime glass, and so this process can be used for display fabrication.

Aluminum flowed to the sidewall of the gate hole. So, the final shape is like the parting layer of the conventional Spindt-type. The reduced diameter of the hole after the reflow process was nearly 1000Å. The extent of the Al reflow was dependent on annealing temperature, annealing time, and layers underneath. The dominant factor of the Al reflow is the interface property between Al and the layer underneath. So, it is very important to select the gate metal. We choose TiW on which Al has a good wettability [2]. Ti, Ti/TiN, $MoSi_2$, and so on, are another candidates. Although the gate metal layer underneath has a bad wettability, if the above material layers are inserted, we can also obtain this Al-reflow characteristics.



(a) (b)

Fig. 2. (a) a non-annealed gated hole, (b) an annealed gate hole at 480℃, 60sec.

Another important factor for the reflow is annealing temperature. Figure 3 presents a tendency of the reduced size of the gate hole diameter versus various annealing temperatures with the annealing time of 60sec. With increased temperature, the diameter was decreased. The conventional Al reflow temperature in the fabrication of DRAM is 550℃, at which Al is reflowed to fully fill a hole, but since we don't have to do, we can carry out the process at a lower temperature.

We finally obtained metal tips by depositing molybdenum by using an electron beam evaporator. Figure 4 shows a SEM photograph of the Mo tip finally obtained. The obtained tip is not different from a usual Spindt-type one. G. N. A. van Veen et. al. reported [3] that metal tips could be formed by using a collimated sputter, which is usually used for the fabrication of semiconductor devices. If we combine our method for a parting layer with the tip formation method using a collimated sputter, it is possible to fabricate field emitter arrays without using the "electron beam evaporator".

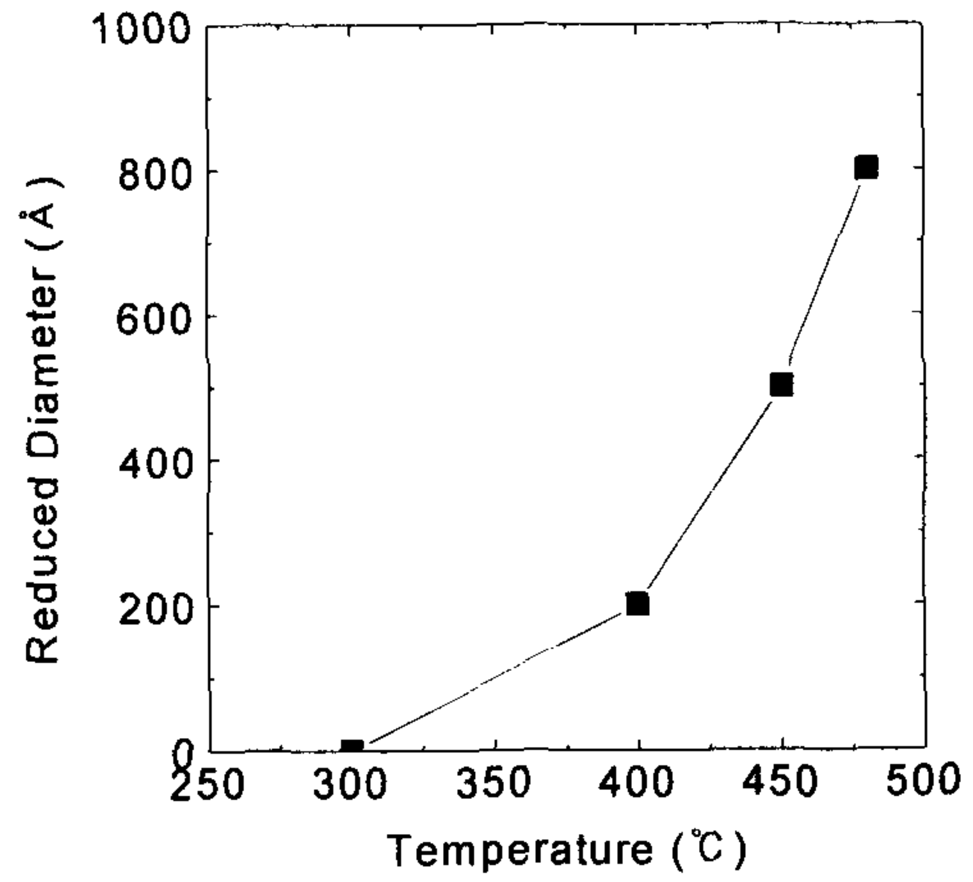


Fig. 3. Reduced diameter of a gate hole versus annealing temperature.

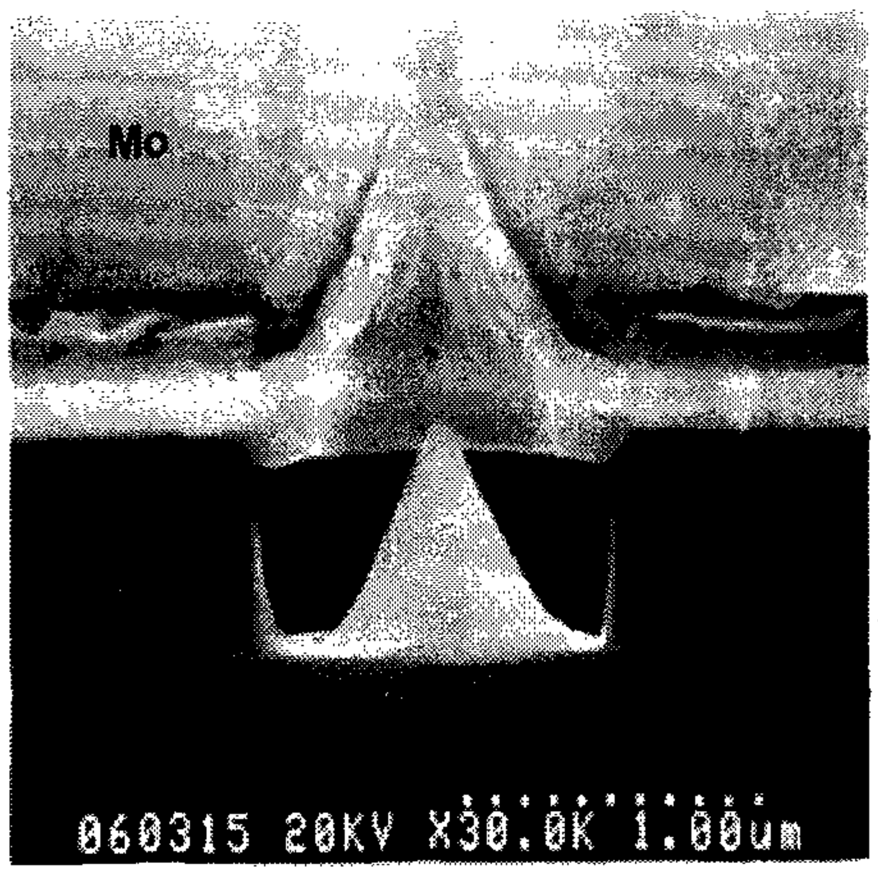


Fig. 4. A Mo tip obtained by using an Al-reflow method.

Conclusion

We present a new method for the formation of an Al parting layer by using the reflow process for metal emitter tips. The temperature of the process was below 480℃, at which glass will not be deformed. By this method, we can obtain an aluminum parting layer without using an electron beam evaporator. If we make use of a collimated sputter, we can obtain tip arrays by a sputtering method, and we can accomplish a large area FED with ease.

References

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