FIELD EMISSION CHARACTERISATION OF SILICON TIP ARRAYS COATED WITH GAN AND DIAMOND NANOPARTICLE CLUSTER

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ABSTRACT

Wide band gap materials show promise for applications in coating of field emission tips. Recently nanocrystalline hexagonal GaN crystallites as small as 5 nm average diameter have been formed using reactive laser ablation of gallium metal in a nitrogenating ambient. In this paper we have investigated the performance of ungated emitter.

Silicon tip arrays coated by dielectrophoresis of gallium nitride nanoparticles or nanocrystalline diamond clusters from an ethanol suspension. The emitters were evaluated and compared before and after the surface treatment using SEM images and I-V measurements in the diode configuration. The phosphor screen, used as the anode was spaced nominally 70 μm from the cathode. A field emission characteristics were measured in a high-vacuum chamber at a pressure range between 10^{-5} and 10^{-8} Torr. The results suggest that the emitters benefit from coating the surface with nanocrystalline diamond clusters in terms of reduction in the turn on voltage and increase in the uniformity of emission in low voltage operation. The long-term emission stability was studied over a period of 90 hrs.

INTRODUCTION

The presence of adsorbed species on the surface of the field-emitter tip can remarkably influence the behavior of electron emission based devices. The presence of the surface contaminants leads to unstable cathode operation. The desirable cathode surface is one that is chemically inert and has a low workfunction. Hence potentially chemically inert emitter-tip overcoatings with wide band gap materials are preferred for a field emission system.

The GaN or diamond nanoparticle cluster is deposited on the surface of the silicon emitters using dielectrophoresis technique. The device configuration considered for the surface treatment of the emitters is the "bed of nails" which is an array of un-gated single-crystal Si emitters placed in an area of 4 cm^2 with a tip-to-tip spacing of 6μm. The emitters were formed from p-type (1-10Ωcm) Si (100) substrates by the subtractive tip fabrication process.

In this work, first results on emission from silicon emitters coated with nano GaN particle clusters are reported. We studied the field emission characteristics and emission stability before and after the emitter surface is coated with GaN nanoparticles or nanocrystalline diamond clusters over an operating cycle of 90 hrs.

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RESULTS AND DISCUSSION

We tested the emission properties of the cathodes in a diode configuration. The packaging of the cathodes containing the array of ungated Si-tips for testing in a high vacuum environment is done by placing quartz spacers, 60 – 70 μm thick between the cathode and the phosphor screen, which acts as an anode.

Both the coated cathodes show an improvement in the long-term stability fluctuation as seen from the Fig 1. Cathodes coated with GaN nanoparticles clusters show significant improvement in the current. With the cathodes coated with GaN nanoparticle cluster, the current is more stable when compared with cathodes coated with diamond nanoparticle cluster. The improvement in the current stability is mainly due to the chemically inert intrinsic behavior of diamond and gallium nitride. It acts as a protective layer for the tip from ion bombardment.

CONCLUSION

In this paper we have studied the behavior of the cathodes coated with GaN nanoparticle and nanocrystalline diamond cluster over an operating cycle of 90 hrs. A comparative study show that emitters coated with GaN nanoparticle cluster show significant improvement in the current fluctuation. Both the coated cathodes show a stable operation during the course of this experiment. Further analysis of the current stability from both these cathodes are being studied

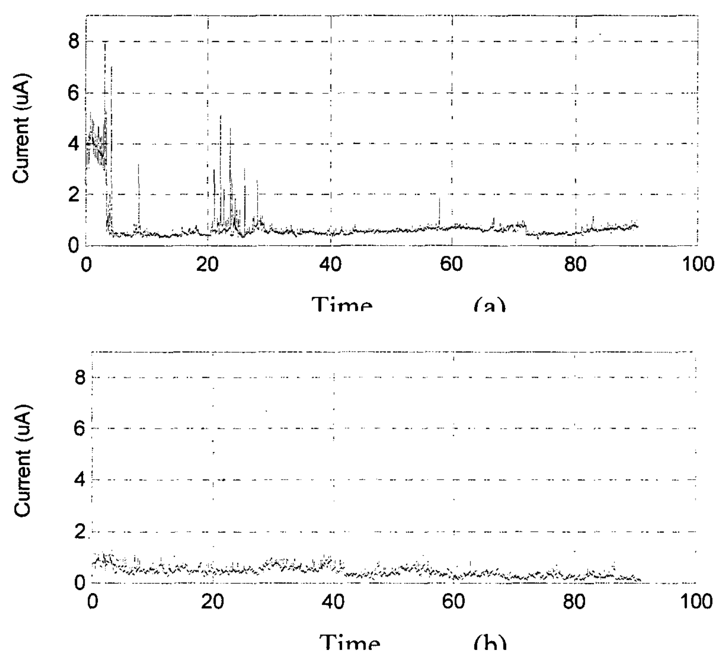

Fig.1 I- characteristics observed over an operating period of 90 hrs for the cathode treated with (a) GaN nanoparticle clusters (b) with nanocrystalline diamond clusters