TOJSR
The Oxford Journal of Science and Research

ISSN No.: 2581-9380
TOJSR, 2020, *3* (1), 1-5

Enhanced Field Emission of Carbon Nanotubes Based Cold Cathode by Silicon Dioxide Buffer Layer

Yawar Alamgeer[1]* S.K.Yadav[2]
[1]*Department of Physics, L.N. Mithila University, Darbhanga, Bihar, 846004, India*
[2]*Principal, Women's College, Samastipur, Bihar, 848101, India*

Abstract: Electron emission is defined as the liberation of free electrons from a surface of the substance into vacuum, caused by external energy transferred to the electron. The emission of electrons from a metal or semiconductor surface under the influence of a strong electric field is called as field emission. Classically, electrons cannot cross the potential barrier if it has less energy than potential barrier but Quantum mechanically electrons has some probability to cross the potential barrier. In our work, a buffer layer of Silicon Dioxide is deposited prior to the catalyst deposition and the Carbon Nanotubes growth was done by thermal chemical vapor deposition method. There was significant improvement in various field emission parameters such as emission current density (J) increases from 1.8 mA/cm^2 to 22.53 mA/cm^2, turn on field (E_T) decreases from 3.4 V/µm to 1.5 V/µm, field enhancement factor (β) increases from 1229 to 9325 and effective emitting area (α) increases from $7.54*10^{-9}$ cm^{-2} to $1.45*10^{-11}$ cm^{-2} by the use of Silicon Dioxide buffer layer. The enhanced field emission properties suggest that the adhesion between Carbon Nanotubes and the substrate increased significantly. The higher current density signifies that the Silicon Dioxide buffer layer lowered the contact resistance and thus longer duration stability was achieved.

Keywords: *Carbon Nanotube, Field Emission, Cold Cathode, Chemical Vapor Deposition, Buffer Layer*

INTRODUCTION

Carbon Nanotubes (CNT's) [1] have excellent physical, mechanical, electrical properties and their potential applications in many peculiar areas like field emitter, nanosensor, fuel storage, nanoelectronics. Previous research investigations have shown that Carbon Nanotubes have outstanding field emission properties [2] due to its very high aspect ratio and very small and sharp tip radius. By virtue of this, Carbon Nanotubes based cold cathode are very efficient electron sources for various applications, including field-emission displays [3], x-ray tubes [4] and electron microscopy [5]. However, the current density obtained from present Carbon Nanotubes based cold cathode is still low. The low current density of CNT based cold cathode emitter is due to many factors, the crucial ones being degradation of CNTs at high electric field [6] and screening effect [7]. It has been predicted that electrostatic screening effect becomes minimum when height of the CNTs is about one half of the inter-nanotube distance [2]. Various schemes have been reported for the minimization of screening effect by growing CNTs bundles with different dot structure and sizes [8-9] rather than growing continuous films of CNTs. Different methods have been reported in the literature for controlling the growth density of CNTs, such as by the capping catalyst particles by deposition of Ti layer [10] and by deposition of buffer layer to enhance the adhesion of CNTs with substrate [11].

In this experiment, we use Silicon Dioxide (SiO_2) buffer layer for minimization of screening effect and improvement of adhesion of substrate and emitters results in increasing the

* *yawaralamgeer@gmail.com*

ISSN No.: 2581-9380
TOJSR, 2020, *3* (1), 1-5

current density. We have carried out our study on two types of samples of CNTs based cold cathode; the first sample without buffer layer referred as reference sample while the second sample having SiO_2 as buffer layer. To evaluate the SiO_2 buffer layer effect on screening, field emission measurement of the above cathodes were carried out in diode mode configuration. Our results validate that the deposition of SiO_2 buffer layer is a major aspect in the enhancement of the field emission parameters of CNT based field emitters.

METHODS

N-type silicon (Si) wafer of low resistivity was taken as a base material or substrate. A thin film of thickness 2 nm of iron (Fe) as catalyst was developed on Si substrate by RF sputtering followed by lift-off. This sample is termed as reference sample. Another sample having SiO_2 buffer layer grown by RF sputtering prior to Fe as catalyst Samples used for the study is 10µm dot with 10 µm spacing. The Growth of CNTs on said samples was carried out by Thermal Chemical Vapor Deposition (CVD) at atmospheric pressure. Initially these patterned samples were heated to 850°C in presence of H_2. Thereafter the samples were pretreated in the presence of NH_3 followed by the introduction of C_2H_2 as the carbon feedstock to carry out the growth of CNTs on both the samples. Then characterizations of these samples were done using Scanning Electron Microscopy.

Field emission studies on reference sample without buffer layer and sample having SiO_2 as buffer layer were carried out in diode configuration. In this arrangement CNTs were used as cathode and mounted on the stainless steel assembly. A stainless steel disk mounted on the same fixture acted as the anode. A screw at the top of the assembly allows us to control the electrode spacing very accurately. In our case the typical electrode spacing was kept at 500 microns. The entire assembly was kept inside a vacuum chamber and evacuated to a vacuum better than 10^{-7} Torr. The emission current measurement was carried out as a function of electric field, under very high vacuum conditions for both the samples of CNTs based cold cathode on silicon substrate.

RESULTS AND DISCUSSION

SEM images of representative samples with and without buffer layer based cathodes prepared by Chemical Vapor Deposition technique are shown in Figure 1 and 2. Desired growth of CNTs has been obtained. The CNTs are found to be vertically aligned via self-supporting mechanism. Due to very high density, the heights of all the CNT samples are similar and are clearly visible from SEM images.

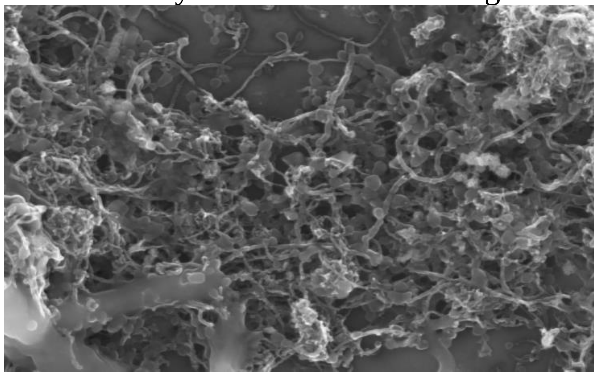

Figure 1-SEM image of reference sample

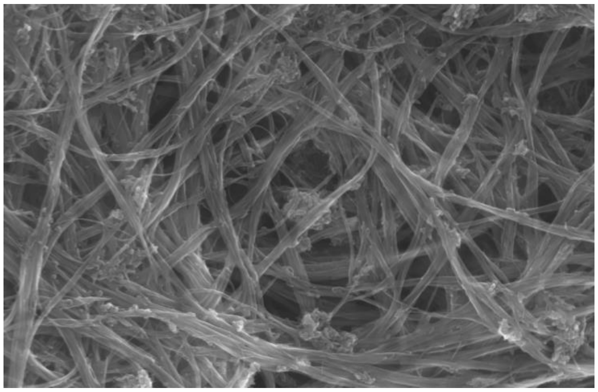

Figure 2-SEM image of sample with SiO_2 buffer layer

The JE plots of the samples are shown in Figure 3 and 4 respectively. It is quite clear from the JE plots that both the samples show the diode characteristics. It is also observed from the

JE plots that the lowest current density viz 1.8 mA/cm^2 was obtained in case of reference sample without any buffer layer shown in Figure 3, and in case of sample with SiO_2 buffer layer the current density obtained is 22.53mA/cm^2 shown in Figure 4. Considering samples, henceforth we observed that the current density for the sample with SiO_2 as buffer layer is more as compared to the reference sample. Though the patterning of dots per unit area in each of samples is same, the current increases in structure having buffer layer. It is clear from Figure 3 and 4, the turn on field decreases from 3.2 V/μm to 1.5 V/μm by using SiO_2 as buffer layer, which clearly confirms our argument that buffer layer is a very effective way to enhance the current density and turn on field.

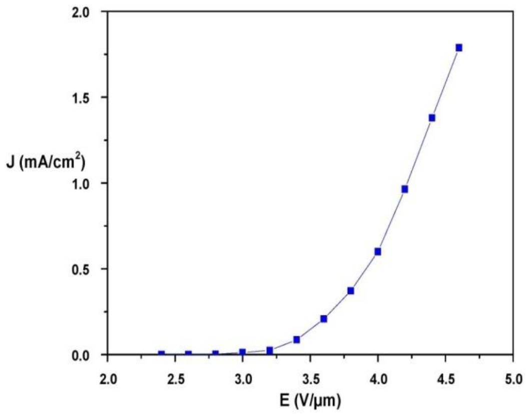

Figure 3-JE plot of reference sample

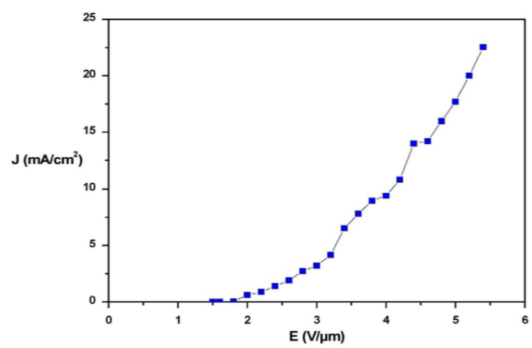

Figure 4-JE plot of sample with SiO_2 buffer layer

The corresponding Fowler-Nordheim plots for both the samples are shown in Figure 5 and 6. The two regions i.e. higher field region and lower field region in the F-N curve for both the samples are clearly visible. However it must be noted that in case of the buffer layered sample the change in slope in two regimes is very small while for reference sample the appearance of the knee is obvious. This can be ascribe to the fact that in case of buffer layer structure there is an exponential and stable increase of current even at high fields. However for the structures without buffer layer, it is clear from the JE plot the increase in current density shows some deviation from expected exponential behavior. This behavior might be due to the elimination of emitting tips at high fields which result in the decrease of tip density during emission. However for the structures with buffer layer, the decrease shielding due to tip elimination at high field does not play a dominant role.

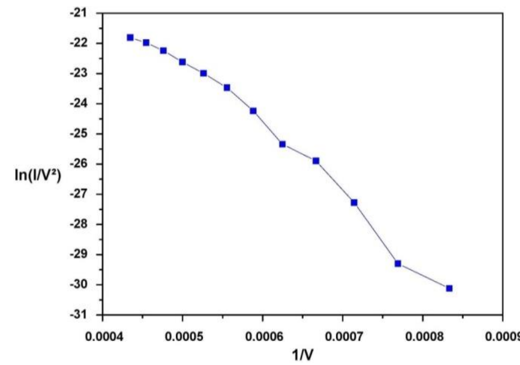

Figure 5-FN plot of reference sample

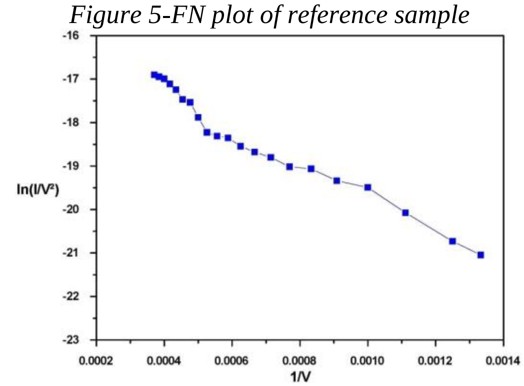

Figure 6-FN plot of sample with SiO_2 buffer layer

In our work, There was significant improvement in other field emission parameters such as field enhancement factor (β) increases from

1229 to 9325 and effective emitting area (α) increases from $7.54*10^{-9}$ cm^{-2} to $1.45*10^{-11}$ cm^{-2} by the use of SiO_2 buffer layer. The emissions from cathodes show a very smooth curve which are almost close to the ideal JE behavior. Results for our cathodes were repeatable for several cycles and also achieved enhanced field emission parameters at comparatively lower electric fields.

Conclusion

In this work we used CVD technique to deposit CNTs film on Silicon (Si) substrates with and without intermediate buffer layer. The first sample without buffer layer is called as reference sample and another with SiO_2 buffer layer. In our work, There was significant improvement in various field emission parameters such as emission current density (J), Turn-on field (E_T), field enhancement factor (β) and effective emitting area (α) increases by the use of SiO_2 buffer layer. The enhanced field emission properties suggest that the adhesion between CNTs and the substrate increased significantly. The higher current density signifies that the SiO_2 buffer layer lowered the contact resistance and thus longer duration stability. These facts are useful and might shed new light on the field emission mechanism for CNTs.

ABBREVIATIONS

CVD- Chemical Vapor Deposition,
CNT- Carbon Nanotube,
FN- Fowler-Nordheim,
SEM- Scanning Electron Microscope,
RF- Radio Frequency,

REFERENCES

1. S. Iijima. *Helical microtubules of graphitic carbon*,Nature, 354 (1991), 56-58.
2. N. D. Jonge and J. M. Bonard, *Carbon nanotube electron sources and applications*," Phil. Trans. R. Soc. A, 362 (2004), 2239-2266.
3. Y. S. Choi, Y. S. Cho, J. H. Kang, Y. J. Kim, and I. H. Kim, S. H. Park, H. W. Lee, S. Y. Hwang, S. J. Lee, C. G. Lee, T. S. Oh, J. S. Choi, S. K. Kang, and J. M. Kim, *A field-emission display with a self-focus cathode electrode*, Appl. Phys. Lett., 82 (2003) 3565.
4. J. Zhang, Y. Cheng, B. Gao, Q. Qiu, G. Yang, Y. Z. Lee, J. P. Lu and O Zhou, *Stationary scanning x-ray source based on carbon nanotube field emitters*, Appl. Phys. Lett., (2005) 184104-184106
5. N. D. Jonge, Y. Lamy, K. Schoots and T. H. Oosterkamp, *High brightness electron beam from a multi-walled carbon nanotube*, Nature, 420 (2002), 393-395.
6. Preeti Verma, Seema Gautam, P. Kumar, P. Chaturvedi, J.S. Rawat, S. Pal, R. Chaubey, Harsh, H.P.Vyas and P. K. Bhatnagar, *CNT Tip Melting with Vacuum breakdown in Cold Cathode*, J. Vac. Sci. Technol. B 25 (2007), 1584.
7. H. J. Jeong, S. C. Lim, K. S. Kim and Y. H. Lee, *Edge effect on the field emission properties from vertically aligned carbon nanotube arrays*, Carbon, 42 (2004), 3036-3039.
8. Harish M. Manohara and Risaku Toda and Robert H. Lin and Anna Liao and Michael J. Bronikowski and Peter H. Siegel, Carbon Nanotube Bundle Array Cold Cathodes for THz Vacuum Tube Sources, J.Infrared Milli Terahz Waves 30, (2009), 1338–1350.
9. Y.M. Wong, W. P. Kang, J. L. Davidson, B.K. Choi, W. Hofmeister, and J. H. Huang, *Array geometry, size and spacing effects on field emission characteristics of aligned carbon*

nanotubes, Diamond Relat., Mater, 14 (2005) 2078-2083.

10. S. Srividya, Seema Gautam, Pika Jha, Prashant Kumar, Anand Kumar, U.S. Ojha, J.S.B.S. Rawat, S. Pal, P.K. Chaudhary, Harsh and R.L. Lai, J.K.Shiu, Y.R. Chang, K.C. Lin, P.C. Chang, C.P. Juan, H.C. Tai, and H.C. Cheng, *Properties of Carbon Nano-tubes Via a Thin Ti Capping Layer on the Pretreated Catalyst*, J. Electro-chem. Soc., 154 (2007), .J109-J115.
11. R.K. Sinha, *Titanium buffer layer for improved field emission of CNT based cold cathode*, Applied Surface Science 256 (2010), 3563–3566