Observations on the effect of coating Nano-Tip Apex with a thin layer of dielectric material on both electron and Ion Emission Mechanisms

Ammar Al Soud[1], Torben Boll[2], Alexandr Knápek[2], Marwan S. Mousa[1]*

[1] Surface Physics and Materials Technology lab, Department of Physics, Mutah University, Al-Karak 61710, Jordan.

[2] Institute of Applied Materials, Karlsruhe Institute of Technology, Karlsruhe 76344, Germany

[3] Institute of Scientific Instruments of the CAS, 147, 612 64 Brno, Czech Republic147, 612 64 Brno, Czech Republic

Introduction

This paper analyses the differences that occurred on field electron emission and ion emission after coating some tungsten tips with a thin layer of dielectric material. Additionally, the mechanism of emission of electrons and ions through channels forming in the dielectric material is described. For the purposes of analysis, the emitters were prepared by coating a tungsten tip with a layer of Epoxylite® resin. A high-resolution scanning electron microscope (HRSEM) was used to monitor the tip profile and measure the coating thickness. Field electron microscope (FEM) and Field ion microscope (FIM) have been used to study both: the emission-current distribution and the emission- ions distribution from the composite emitters. Two forms of emission patterns have been observed: a multi-spot pattern, from the clean emitters with irregularity in the substrate, and a bright single- spot pattern, from coated emitters with a high substrate.

Methodology

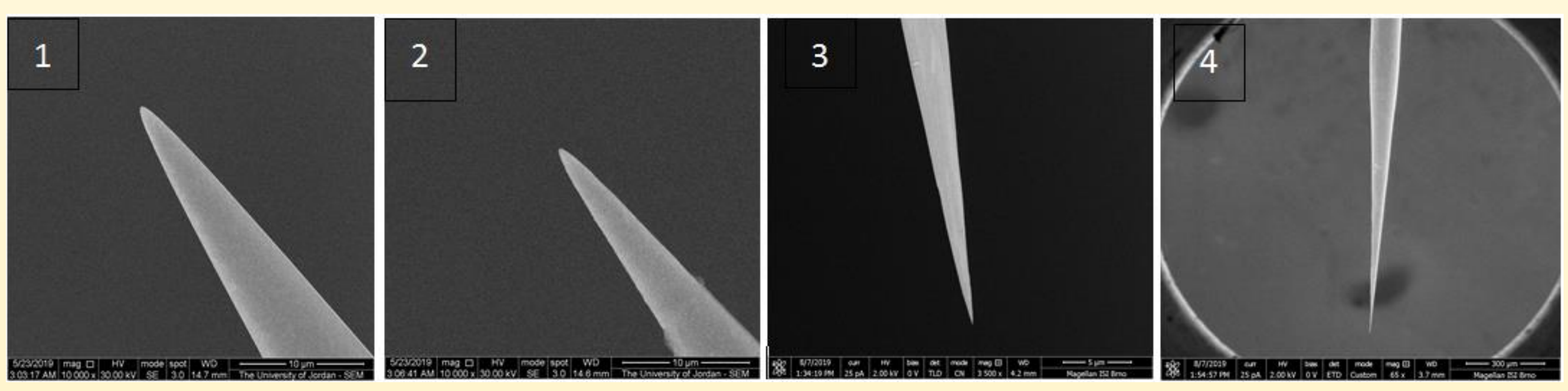

Fig.1: SEM images for uncoated emitters from 1 to 4.

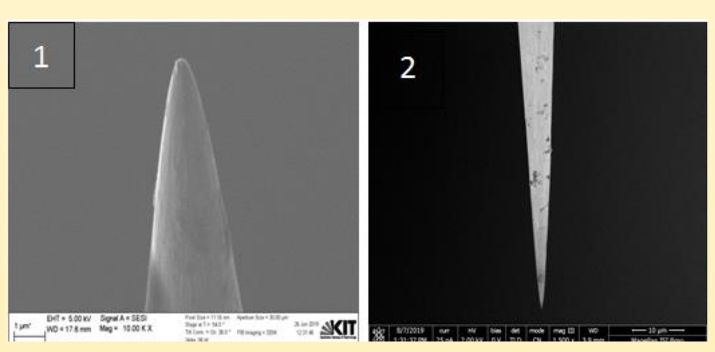

Fig.2: SEM images for composite emitters 3 and 4 (tungsten / UPR-4 resins) , the thickness of epoxy layer is 150 and 30 nm rrespectively.

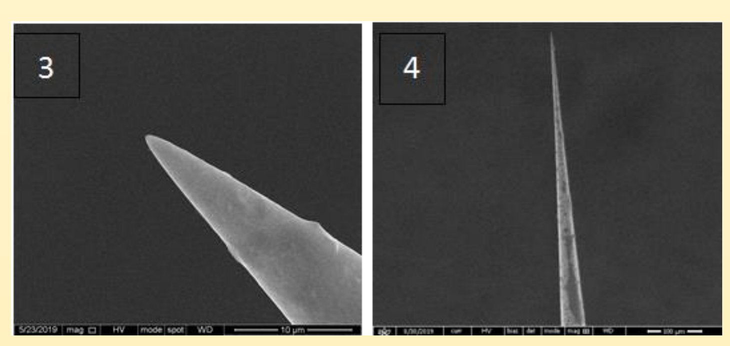

Fig.3: SEM images for composite emitters 3 and 4 (tungsten / 478 resins) , the thickness of epoxy layer is 150 and 30 nm rrespectively.

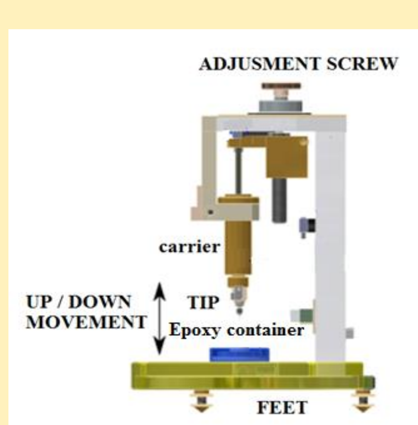

Fig.4 The setup used for coated the W tips.

Results

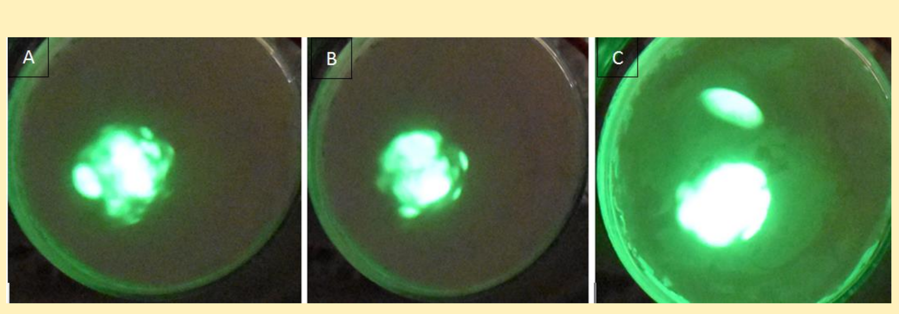

Fig. 5. FEM pattern structure for uncoated emitter 1 primarily consists of a multi spots. A) 2 µA at 2,000 V. B) 2.3 µA at 2,200 V. c) 2.7 µA at 2,500 V. Time separation between consecutive images is 15 minutes.

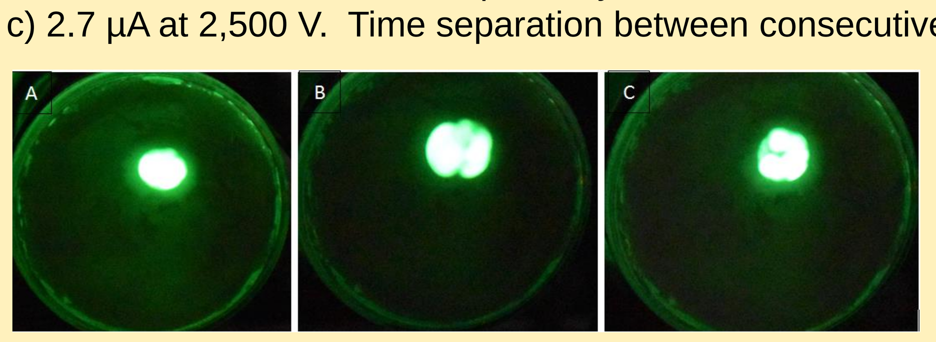

Fig. 6. FEM pattern structure for composite emitter 1 (Tungsten/ UPR- 4 Resin), the thickness of epoxy layer r is 150 nm. Primarily consists of a single bright spot. A) 3.2 µA at 2.000 V. B) 4.4 µA at 2,400 V. c) 5.6 µA at 2,500 V. Time separation between consecutive images is 15 minutes.

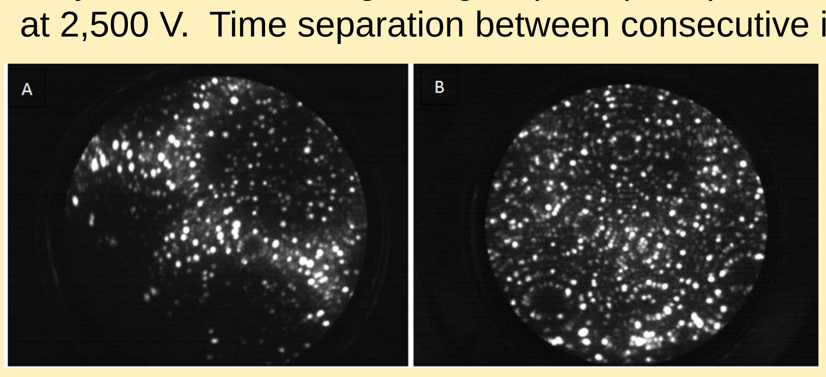

Fig. 7. FIM patterns for uncoated emitter 2 primarily consists of a multi small spots, A) Applied field is 3.5 kv and temperature is 75 k B) Applied field is 5 kV Applied field is 75k.

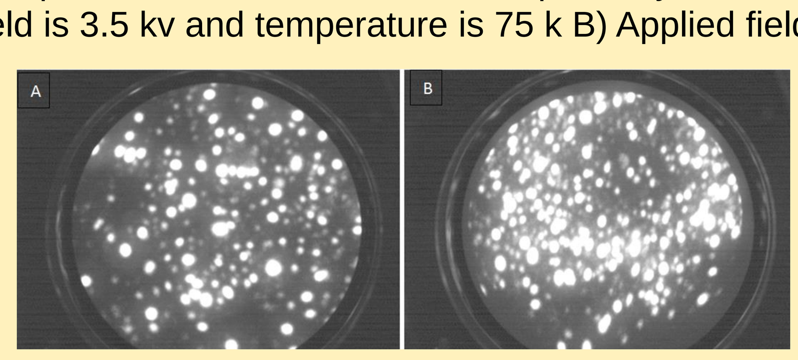

Fig. 8. FIM pattern structure for composite emitter 4 (Tungsten/ 478 Resin), the thickness of epoxy layer is 30 nm. Primarily consists of a multi big and bright spot. A) Applied field is 4000 V and temperature is 75K. B) Applied field is 5000 V and temperature is 75K.

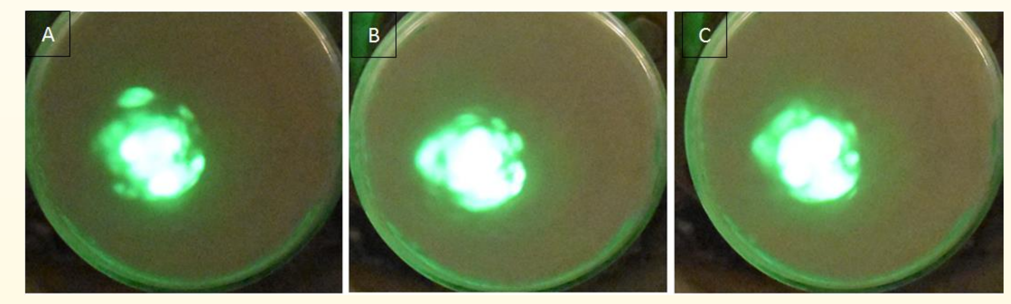

Fig. 9. FEM pattern structure for uncoated emitter 2 primarily consists of a multi spots. A) 2.2 µA at 2.200 V. B) 2.4 µA at 2,400 V. c) 2.9 µA at 2,500 V. Time separation between consecutive images is 15 minutes.

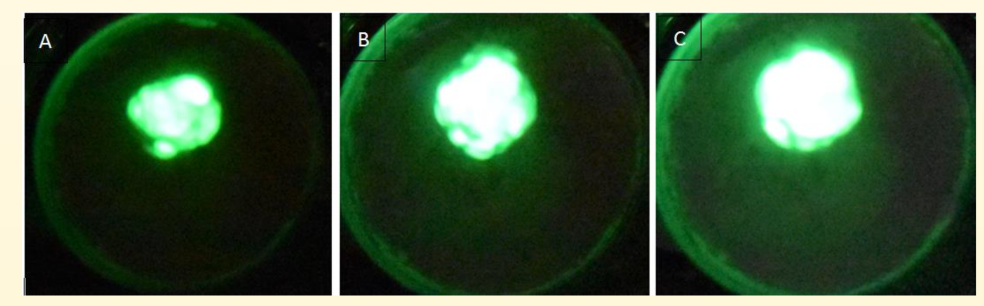

Fig. 10. FEM pattern structure for composite emitter 2 (Tungsten/ 478 Resin), The thickness of epoxy layer is 150 nm. Primarily consists of a single bright spot. A) 4.3 µA at 2.300 V. B) 5.4 µA at 2,500 V. c) 6.8 µA at 2,600 V. Time separation between consecutive images is 15 minutes.

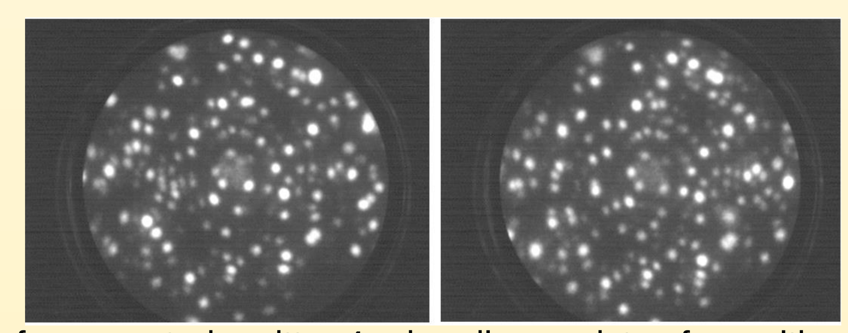

Fig. 11. FIM patterns for uncoated emitter 4 primarily consists of a multi small spots, A) Applied field is 3.2 kv and temperature is 75 k B) Applied field is 5.3 kV and temperature 75k.

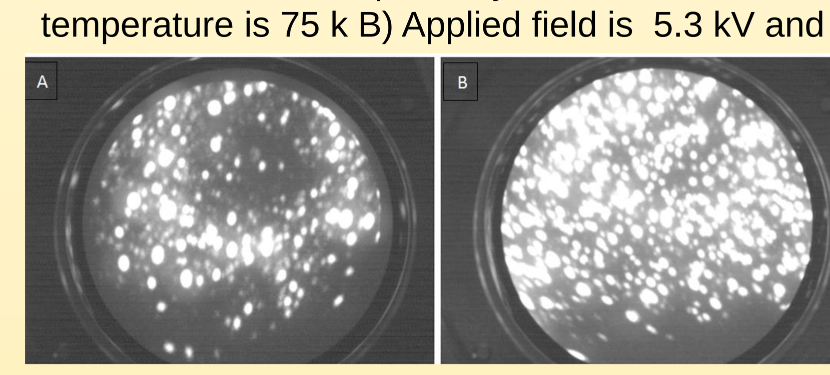

Fig. 12. FIM pattern structure for composite emitter 4 (Tungsten/ 478 Resin), the thickness of epoxy layer is 30 nm. Primarily consists of a multi big and bright spot. A) Applied field is 4000 V and temperature is 75K. B) Applied field is 5000 V and temperature is 75K

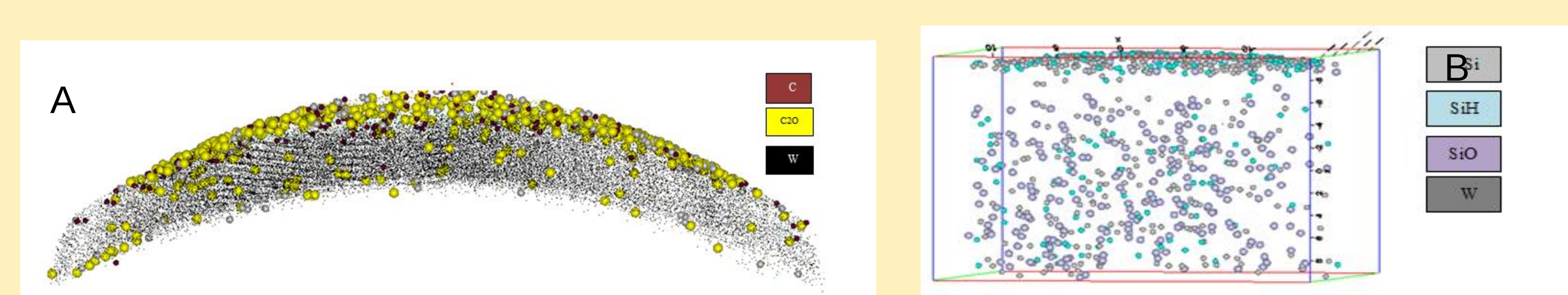

Fig. 13 the shape of the emitters obtains on the APT measurement, A) emitter I. B) Emitter 3.

B

Fig. 14. A) APT for composite emitter 1. **. B)** APT for composite emitter 3,

Conclusion

In From the above, it was noted that there is a similarity in the emission of electrons and ions after coating the emitters with an epoxy layer.so, it can be concluded that an electrons and ions sources producing a single bright or multi bright field emission spots have been produced employing a combination of a composite emitter (tungsten / epoxylite resin). These emitters interesting as potential electron and ions sources. This behaviour can be explained by forming conductive channels between the apex tip and the resin / vacuum surface. The epoxy layer has several benefits such as forming channels as a conductive medium, and increase the life time for the emitter, through save the tip from ion back bombardment which normally damages this emitting tip after sometime.

References

1 - Forbes, Richard G. *Ultramicroscopy* 95 (2003): 1-18.

2 - R. V. Latham and M. S. Mousa. J. Phys. D: Applied Physics 19, 4, 699 (1986).

3 - M. S. Mousa, Le Journal de Physique Colloques, Vol.486, C6-109. (1987),

4 - Ala'a, M., & Mousa, M. S., Electrons. Applied Microscopy, Volume46 , Number 3 (2015) 155-159.

5- Forbes, R. G., Deane, J. H., Fischer, A., & M. S. Mousa, JJP. Volume 8, Number 3, 2015. pp. 125-147 (2015)

6 – R.G. Forbes, arXiv preprint arXiv:1905.07585 (2019).

7 - Knápek, A., & L. Grmela, Methods of preparation and characterisation of experimental Field-emission cathodes. Vysoké učení technické. (2013).

8 - Boll, T., Al-Kassab, T., Yuan, Y., & Liu, Z. G., Ultramicroscopy, Vol. 107, P. 796-801(2007).

9 - Boll, T., Unocic, K. A., Pint, B. A., & Stiller, K. Microscopy and Microanalysis, Vol. 23, P. 396-403 (2017),.

10 - Mousa, M. S. A Doctoral dissertation, University of Aston in Birmingham (1984).