FIELD EMISSION DEVICES ELECTRICAL CHARACTERISTICS TRIAL SYSTEM

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ABSTRACT

This work presents a dedicated equipment developed in order to obtain the electrical characteristics of FE (Field Emission) devices automatically. The trial system is composed by hardware and software: the hardware is a high voltage source connected to a computer by serial communication over RS-232 standard, and the software was developed in Borland Delphi (version 7) environment. A computer program was elaborated in order to manipulate the system control easily applying the virtual instrumentation concept. Its main characteristics are: configuration of source parameters, storage data and visualization of the results "on-line" through graphs. With these, it is possible to investigate behavior and tendencies of the devices, to modify range of voltage or other parameters (if necessary) during the experiment.

1. INTRODUCTION

FE devices are composed by two electrodes (anode and cathode), integrated or not. The cathode can emit electrons, at room temperature, by applying a strong electric field. The experiments carried out indicate that the emission current from field emitters (including silicon) is not very stable. Large fluctuations in the emission current are often noticed and over a period of time the decay of this current can also be quite significant [1]. Due to this instability, FEs need analysis to verify changes on their operation along time, so this is one major difficulty to characterize these devices. On the other hand, to make manual notes of measurements from analogic instruments of these trials is very hard, because these trials can take hours. Thus, the development of instruments able to take trial samples and record automatically and a system which can be easily operated remotely is very important.

In this sense, a trial system was developed under the “virtual instrumentation” concept, composed by hardware and software. The hardware receives parameters from the software, actuates under the trial characteristics, and sends back data about the course of trial when asked. The software was developed to manage all data handling collected from the hardware during the trials, and showing, as final results, "on line graphics plotted" and data trial readings, with easy manipulation of trial parameters by users.

This instrument uses the serial communication on RS-232 standard as the main interface between hardware and software.

It is important to mention that the project was developed leaving many possibilities open to be improved in the future.

2. EXPERIMENTAL PROCEDURE

Electrical measurements were made using 2500 silicon tips array field emission devices fabricated by HI-PS technology in the Laboratório de Microeletrônica da USP [3]. The distance between tips top is 75 µm enclosed in a square area of 9 mm^2.

2.1. Trial system chamber

A stainless steel vacuum chamber was developed to characterize FE devices, which need to operate at low pressure environment (about 10^{-6} Torr or less), thus, the chamber was connected to a turbomolecular and dry-mechanical vacuum pumping system. The silicon substrate with microtips is placed over a stainless steel plate electrically grounded (cathode), and the high voltage is applied on another stainless steel plate (with 20 mm of diameter) used as the anode electrode [2] (Fig. 1). The distance between cathode (microtips) and anode can be externally adjusted by a micropositioner coupled with the cathode structure.

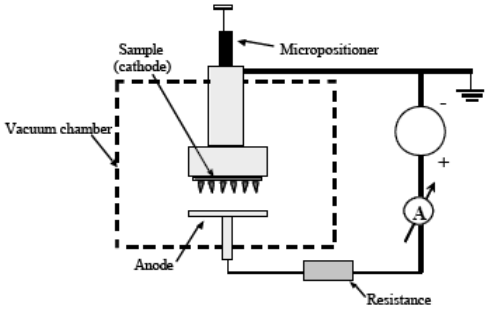


Figure 1 – Schematic diagram of the test system

2.2. Hardware

Fig. 2 shows the block diagram of the hardware developed.

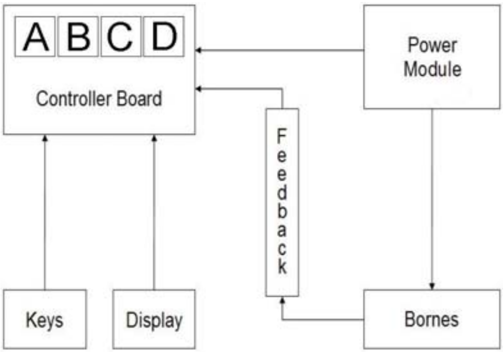
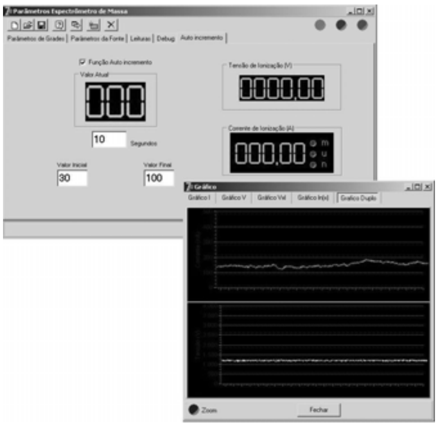


Figure 2 – Hardware diagram

The controller board has a dedicated microcontroller produced by Microchip® (PIC18F452) which is responsible for all the resources available in this equipment. It acts as the "brain" of the equipment, and all information passes through it. The controller board has four blocks with the following functions: (A) is responsible for the primary voltage generation, (B) is responsible for sending and receiving the communication data between the source and the computer, (C) is responsible for performing his directly at the primary power module circuit, and (D) is responsible for interacting with the microcontroller while the source is under operation. This is possible due to feedback circuits.

2.3. Software

The software, named "*HighVolt Controller*", was developed with the Borland Delphi 7 tool. This software is responsible for managing all inputs done by users, showing all outputs, through displays, data bases, or by graphics. In this sense, this software manages all the "high voltage source" functions and resources as well. Figure 3 shows two illustrative windows of the software *HighVolt Controller*, where on the left is the window where the user can input the parameters for automatic trial with auto-increment of output voltage, and on the right is the window where it is possible to select and to visualize the plotted graphs.



☑ Função Auto incremento

Valor Atual: 000

10 Segundos

Valor Inicial: 30

Valor Final: 100

Tensão de Ionização (V): 0000,00

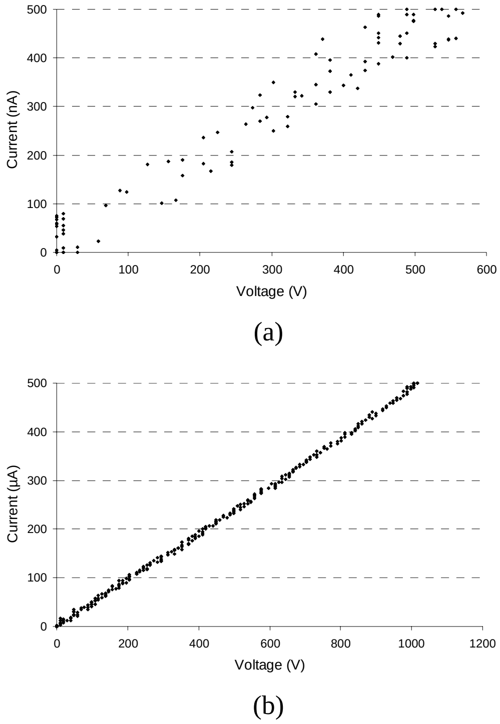
Corrente de Ionização (A): 000,00

Figure 3 – Illustrative windows of the software *HighVolt Coltroller*

The main resources of the software are listed as follows: 1) Configure the source parameters, grating and the scales to be used; 2) Transfer all parameters configured by the users to the source, before or during the operation; 3) Record the configurations parameters; 4) Recover parameters recorded previously; 5) To turn on or off the source without physical contact, that is, remotely; 6) Select the speed of graph updating; 7) Select different kinds of graphics visualization (I-V, I-t, V-t, Fowler-Nordhein or I-t and V-t simultaneously), or verify some other information through the displays; 8) Change the current reading scale manually or automatically; 9) Export data bases recorded during the trials to be used by other software. 10) Use different instrument modes as required: Manual Control, Current Control or Voltage Control.

3. RESULTS AND DISCUSSION

Figure 4 shows obtained I-V plots done to validate the calibration of the trial system. They show the system response for (a) minimum current scale (500nA) and the response for (b) maximum scale (500µA). The calibration process was made by resistors validated by Precision Semiconductor Parameter Analyzer Model HP4156A.



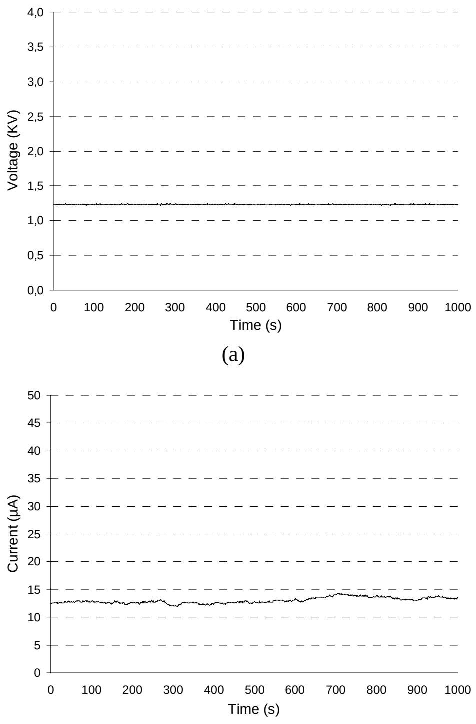
(a)

(b)

Figure 4 – Validation Graph of (a) lower and (b) higher current scales

As expected, I-V plots for resistor can be well fitted for straight lines and, at lower scale (Fig. 4a), the data dispersion is more evident. This dispersion is about 100nA. At a higher scale (Fig. 4b), the data dispersion becomes imperceptible. This visual difference is due to the fact that dispersion of 100nA in the 500nA scale is about 20%, while 100nA in the 500µA scale is about 0.2%.

Figure 5 shows two examples of graphs plotted "on-line" and data exported later. They were extracted from trial of a silicon non-integrated FE device obtained by HI-PS technique [3]. The first one, Fig. 5a, shows the course of output voltage along time. The second one, Fig. 5b, shows the course of output current along time.



(a)

(b)

Figure 5 – Sample of real plots from the trial system of microtips Sample X57D: (a) Voltage and (b) Current along time.

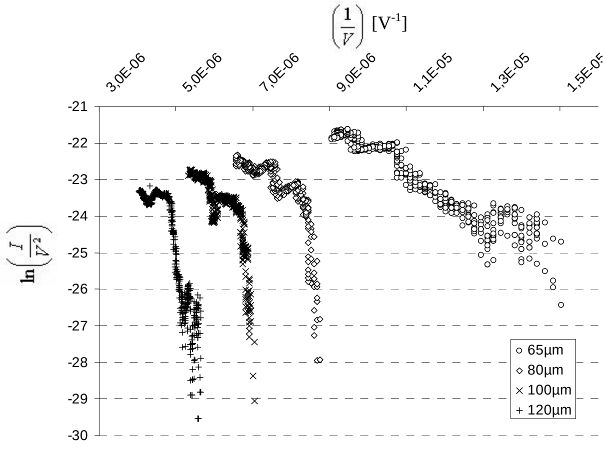


Figure 6 – Sample of a Fowler-Nordheim graph for Si sample

Figures 6 and 7 show an example of a Fowler-Nordheim (F-N) graphic [4][5], that can be applied to verify the quality of FE device and its agreement with F-N theory, and a Current versus Voltage graphic respectively, extracted from the system of another real trial. In this trial, the distance between microtips and the anode was changed to evaluate the field emission performance. These graphs show how instable is the emission current from field emitters. To solve this instability, research groups work developing new materials, new manufacture methods or superficial treatment of the field emitters.

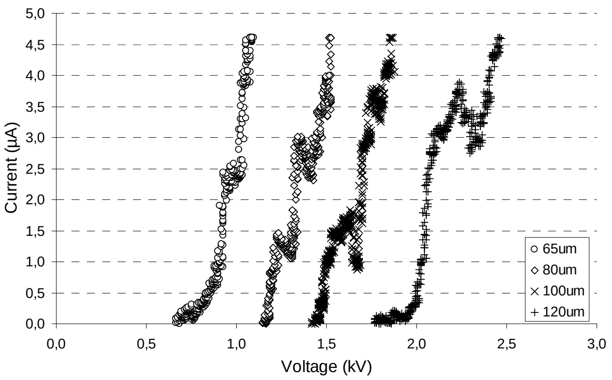


Figure 7 – Sample of a V-I graph

4. CONCLUSIONS

This paper presents the evaluation of a trial system with the "virtual instrumentation" concept, developed for electrical characterization of FE devices. Through a calibration process, it was possible verify that the system operates properly as expected.

Next steps of this work will be focused on the improvement of the electrical characterization system to obtain a large range and precise experimental points to allow the study of other relevant parameters for FE devices, such as the influence of geometrical dimensions of the tips and its long-term degradation.

Nowadays the group has been working in order to have the power module performance improved.

In this way, it was demonstrated that, from simple components, it was possible to develop solutions that meet our needs with good performance and low cost.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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