Experimental installation for study the low-power ICRF plasma at low pressures with equipment for experiment data synchronization

To cite this article: T N Terentev *et al* 2022 *J. Phys.: Conf. Ser.* **2270** 012014

Experimental installation for study the low-power ICRF plasma at low pressures with equipment for experiment data synchronization

T N Terentev[1], V S Zheltukhin[1, 2], A Yu Shemakhin[1], I K Nekrasov[1], E S Samsonova[1, 2], E Yu Shemakhin[1], I E Tsokalo[3], V A Tyurin[1]

[1]Kazan Federal University, Kazan, Russian Federation
[2]Kazan National Research Technological University, Kazan, Russian Federation
[3]Medical Academy named after S.I. Georgievsky of V.I. Vernadsky Crimean Federal University, Simferopol, Russian Federation

shemakhin@mail.com

Abstract. An installation for numerical and experimental studies of low-pressure radio frequency plasma for surface modification of functional materials with equipment for data synchronization are presented. The equipment for data synchronization as well as intermediate results for plasma generation are showed.

1. Introduction
There are two main methods of cold RF plasma generation: capacitive coupled plasma (CCP) and inductive coupled plasma (ICP) [1]. In ICP electromagnetic energy is transmitted from a RF generator to plasma in a wide range of frequencies from 1 to 50 MHz, and gas pressure in range from 10 upto 1000 mTorr; the optimal frequency range is 0.05-13.56 MHz [2]. One of the advantages of this kind of plasmas is its temperature ("cold" plasma), so material surface is not heated to critical temperatures at processes ofplasma modification of different materials [3, 4]. The installation will let us to verifyresults of mathematical simulation of nonlinear processes occurring in the low pressure RF plasma [5, 6], as well as processes of interaction with a sample. Special attention is paid to synchronization of incoming data such as gas flow rate, gas pressure in a vacuum chamber, temperature, and electron energy distribution function (EEDF).

2. Another section of your paper
The main elements of the installation are RF generator, vacuum chamber, ESPION Probe Interface Unit (EPIU), Langmuir Probe, flowmeter and its control unit, thermocouple, manometer, rotary pump. The block diagram of the installation one can see on Fig.1.

RF generator was assembled on IRFP250N transistors. The frequency of RF generation is 1.76 MHz. This frequency was chosen in accordance with the article [2]. As follows from experimental data, the minimum value of the rotary pump in the vacuum chamber is 0.6 Torr. The vacuum chamber and the RF generator were placed in a steel box to shield the radiation and to avoid the penetration of electromagnetic radiation into the diagnostic environment. Other elements such as the flowmeter, EPIU, manometer (which is an analog device) were placed outside the box to avoid the influence of electromagnetic radiation. The power of the generator is approximately 30 W. The generator was designed so that the RF frequency is variable from 1.76 to 40 MHz. An example of plasma generation without argon flow is shown in Fig. 2(a).

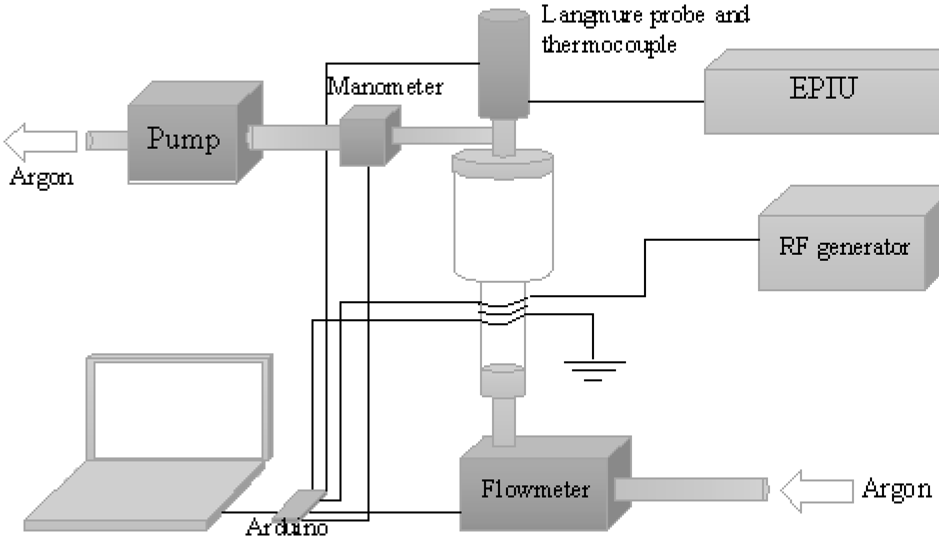

Figure 1. Installation block diagram.

The device MKS M100B having a maximum gas flow of 20 sccm was selected as the flowmeter. It is designed for regulation the flow of argon into the vacuum chamber. The minimum step of flow variation is 0.2 sccm. The device is analogue type; it is configured with a connector type D 15 pin. It was decided to realize the project of flowmeter control based ona small, complete, and breadboard-friendly boardAurduino Nano (AN). The main feature of AN for using in installation is a plotter on a serial connection in the program Aurduino IDE. AN has analog and digital pins. However, the analog pins can only receive a signal, and digital pins can’t conduct current more than 50 mA. Thus, the plotter on one of the analogue pins plot the signal in real time.

M100B transmits the value of argon flow from 0 to 5 V. Thus, the plotter on one of the analogue pins in real time can plot the received signal. Flowmeter transmits the value of argon flow from 0 to 5 V by 8 pins. This signal is plotted in real time in the plotter. Then the data from the COM-port (in the plotter window) are copied into *.xlsx* format, and then the program converts the ordinate axis from volts to sccm. There is a direct proportional relationship between voltage and flow value. Adjustment by the argon flow is performed by the DC voltage block from 0 to 5 V. Flow regulation with AN is difficult because only digital pins work in OUTPUT mode and it has current limitation. At the maximum gas flow value, the M100B consumes 350 mA by the flow control pin. An example of plasma generation with argon flow can be seen in Fig. 2(b).

EPIU receives the signal from Langmuir Probe and plots the EEDF graph. Test current-voltage characteristics for 50k resistor in ESPsoft program interface are shown in the figure. 3.

The plasma setup consists of a discharge tube and a vacuum chamber. At pressures more than 1.5 Torr plasma is not generated in the plasmatron because of weak power of generator. Therefore, the task was to select plasmatron materials (more precisely, flanges that are connected to the quartz discharge tubein combination with vacuum sealant) that will withstand low pressure. It was found that PLA plastic in combination with vacuum sealant rebuff low pressure for a long time and allows to use the pump life to the maximum. Therefore, the lower, intermediate and upper flanges of the vacuum chamber were made of PLA plastic. The melting point of PLA plastic is 403 K and that of silicone sealant is 513 K. For this reason, these materials do not have direct contact with plasma in the space between the discharge tube and the vacuum chamber due to the indentation from the end of the plasma torch to the attachment point of the main vacuum chamber.

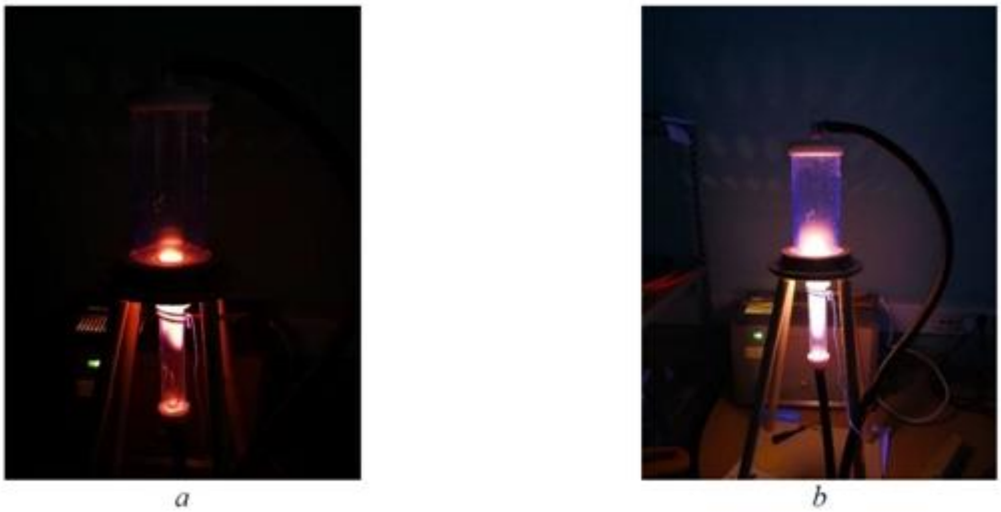

Figure 2. Plasma generation without (a) and with (b) argon flow in plasma equipment.

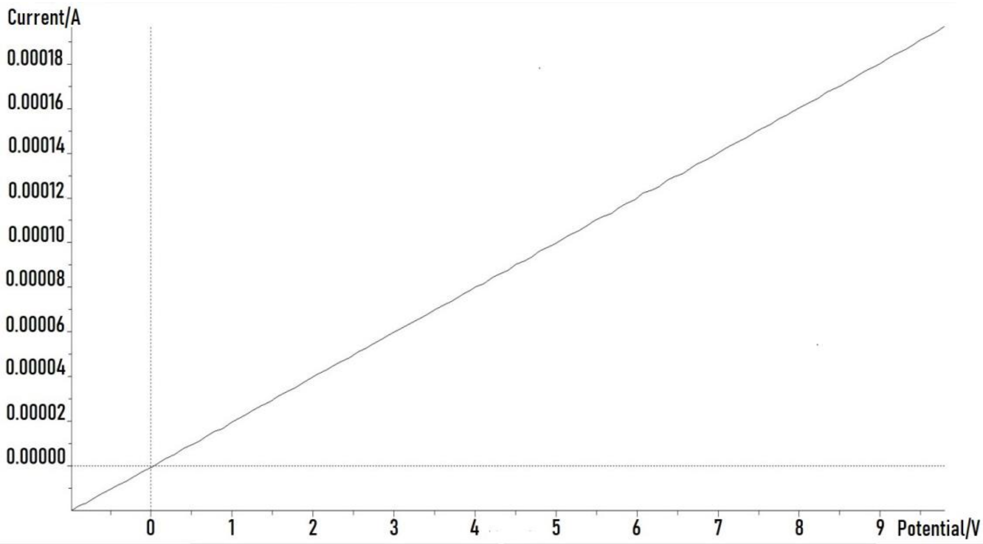

Figure 3. Current-voltage characteristics for 50k resistor in ESPsoft.

3. Equipment for data synchronization system

The data synchronization system includes a flowmeter, manometer, thermocouple, oscilloscope and EPIU. EEDF charts with EPIU are displayed on a separate screen for more convenient data processing. The interface is showed on the figure. 4.

Data from the flowmeter and manometer are fed to the AN, high voltage probes and thermocouple signals on the Arduino UNO. Through the serial COM-port the graphs are built in real time. Data from the secondary winding of the RF generator output transformer are taken off the high voltage probe, which has a built-in attenuator at 30 dB in amplitude. The signal is received by Arduino UNO, which transmits the data to a PC. Measurements are displayed in a special program that acts as an oscilloscope.

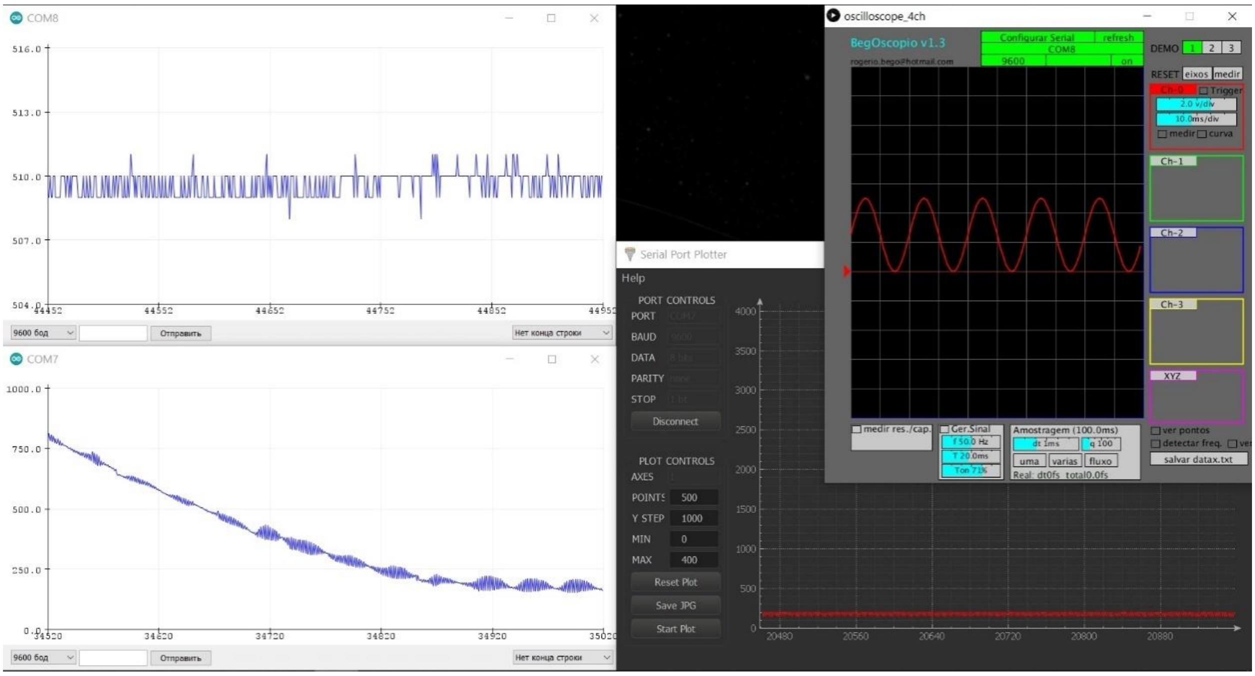

Figure 4. Data synchronization of temperature, pressure and argon flow rate.

Before recording EEDF, it is necessary to ensure the accuracy of the set and measured parameters such as temperature, pressure and gas flow. Only then EEDF measurements can begin. To ensure that temperature and pressure data are not mixed with data prior to recording the EEDF, a sketch is updated when starting the EEDF measurements and all available temperature and pressure data in the cache is reset with the sketch.

Acknowledgment
The study was funded by Russian Science Foundation, project № 19-71-10055.

References

[1] H. Conrads, M. Schmidt, Plasma generation and plasma sources, Plasma Sources Sci. Technol. 9 (2000) 441 – 454.
[2] Lieberman M. and Lichtenberg A. 1994 Principles of Plasma Discharges and Materials Processing (New York: Wiley)
[3] GrillA.1994 Cold Plasma in Materials Fabrication: from Fundamentals to Applications, IEEE Press, New York.
[4] AbdullinI.Sh, Zheltukhin V.S., Sagbiyev I.R., and Shayekhov M.F. 2007 Modification of nanolayers in radio-frequency discharge at low pressure [Modifikaciya Nanosloev v vysokochastotnoj Plazme Ponizhennogo Davleniya – in Russian] (Kazan: Kazan Technol. Univ. Press [Izdatel'stvo Kazanskogo Tekhnologicheskogo Universiteta])
[5]Badriev, I.B., Chebakova, V.Y., Zheltukhin, V.S.(2017) Capacitive coupled RF discharge: Modelling at the local statement of the problem,J. Phys. Conf. Ser.**789**(1) 0120048
[6]Shemakhin, A. Y., andZheltukhin, V. S., Mathematical Modelling of RF Plasma Flow at Low Pressures with 3D Electromagnetic Field, Advances in Materials Sci. and Eng. (2019)7120217