LASER PLASMA SPECTRAL CHARACTERISTICS FOR COMBINED MAGNETRON AND LASER DEPOSITION

A Burmakou[2], O Lyudchik[3], V Kuleshov[4], D Saladukha[1]

Belarusian State University, 4 Nezavisimosty ave., Minsk, Belarus, [1]Den.solo.by@gmail.com
[2]Burmakov@bsu.by, [3]Lyudchik@tut.by, [4]KuleshovV@Yandex.ru

Abstract

The paper discusses the installation of combined pulsed laser and magnetron deposition of thin-film structures with controlled plasma flow conditions and the ability to study the plasma parameters. Two-pulse laser plasma spectral features are presented. A method to enhance energy, charge and elemental composition of the formed plasma as the main components in the thin film deposition process is released.

Experimental setup

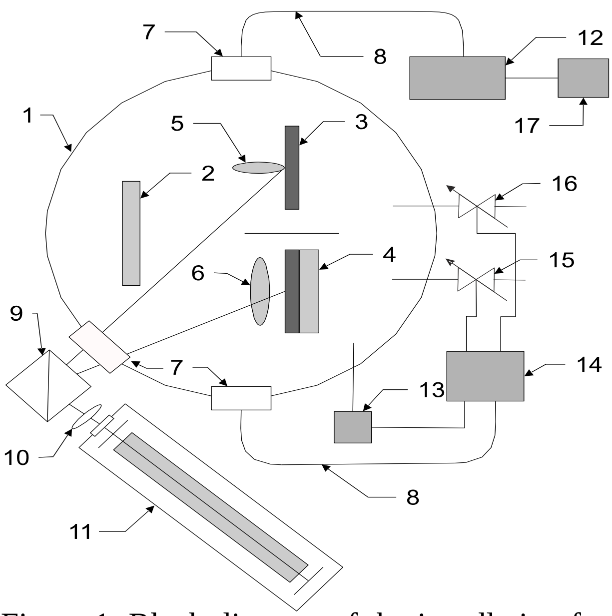

Figure 1. Block diagram of the installation for the laser-magnetron coating: 1 - vacuum chamber, 2 - substrate holder, 3 - laser sputtering target, 4 - magnetron, 5 - laser plasma, 6 - magnetron discharge plasma, 7 - quartz windows , 8 – optical fibers, 9 - laser beam scan device, 10 - focusing lens, 11 - two-pulse frequency laser, 12 - spectra detector, 13 - pressure sensor 14 - gas flow control system, 15 - argon valve, 16 - reactive gas (O_2, N_2, etc.) valve, 17 - computer

Figure 1 presents the experimental setup for laser and magnetron thin film deposition. As the laser source two-pulse frequency Nd:YAG laser 11 was used. Laser beam is directed into the vacuum chamber 1 through a focusing lens 10 by means of a prism complex 9 through the quartz glass 7. Laser beam is directed to the cathode of magnetron 4 or a separate laser target 3. Thus, the installation allows a joint or separate ignition laser and magnetron plasma /1/. The optical radiation of plasma left the chamber 1 through the window 7 of quartz glass, and is caught in a quartz optical fiber 8, then enters spectra detector 12. For the spectra recording it was used the S100 spectrometer, which has a spectral resolution of about 1 nm, or a monochromator with the CCD-line instead of the exit slit which improves the spectral resolution to 0.1 nm. Spectral range of the S100 spectrometer is 200-1000 nm. By means of the monochromator with the CCD-line the emission spectrum is recorded in the 75 nm width ranges. The gases flow control for magnetron deposition has been performed with the use of the /2/ optical system 14 based on the S100 spectrometer.

Spectral analysis

On the example of Ti plasma it was analyzed the main features of the laser plasma. The general form of the laser and magnetron plasma spectra are shown in Figure 2 and Figure 3 respectively. The spectra were recorded by the S100 spectrometer.

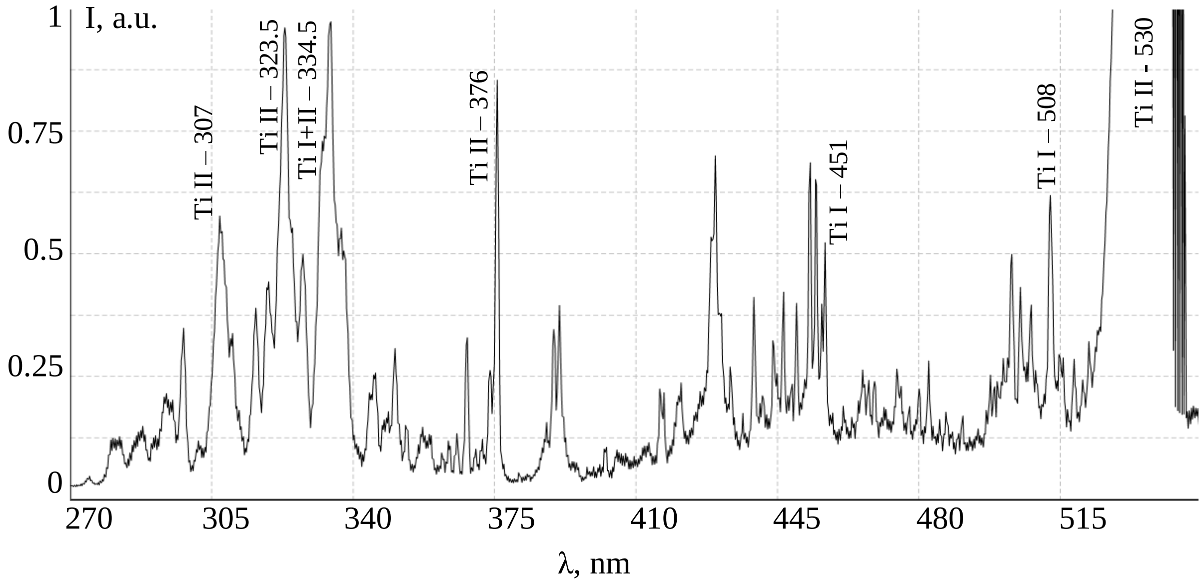

Figure 2. Part of the Ti laser plasma spectrum in the wavelength range of 270-530 nm

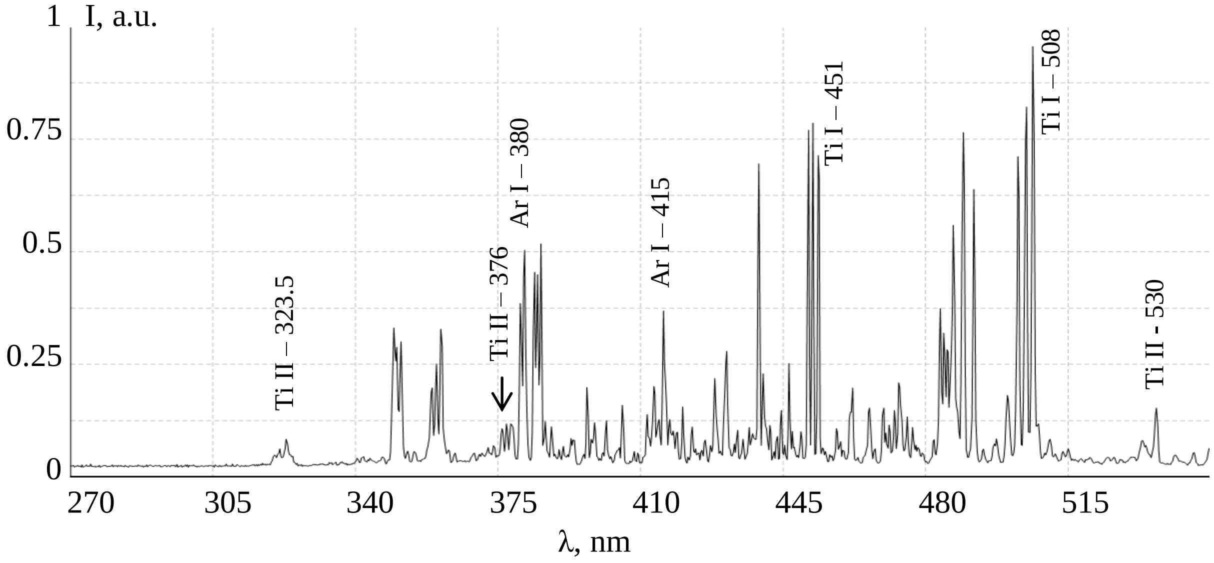

Figure 3. Part of the Ti magnetron plasma spectrum in the wavelength range of 270-530 nm

A comparative analysis of these spectra showed that the laser plasma spectral lines in the wavelength range of 300-500 nm were strongly merged with each other, which indicated the high plasma density and the presence of a significant proportion of the ionic component compared to the magnetron plasma. In magnetron plasma spectra Ti II spectral lines are not intensive compared to Ti I. In laser plasma spectra Ti II spectral lines were detected as well as Ti I. The result is laser spectral lines high density. In order to resolve the spectral lines in a narrow range of the spectrum the monochromator with the CCD-line was used. Figure 4 represents part of the laser plasma spectrum in the range of 305-370 nm, which shows a set of lines that are not permitted by S100.

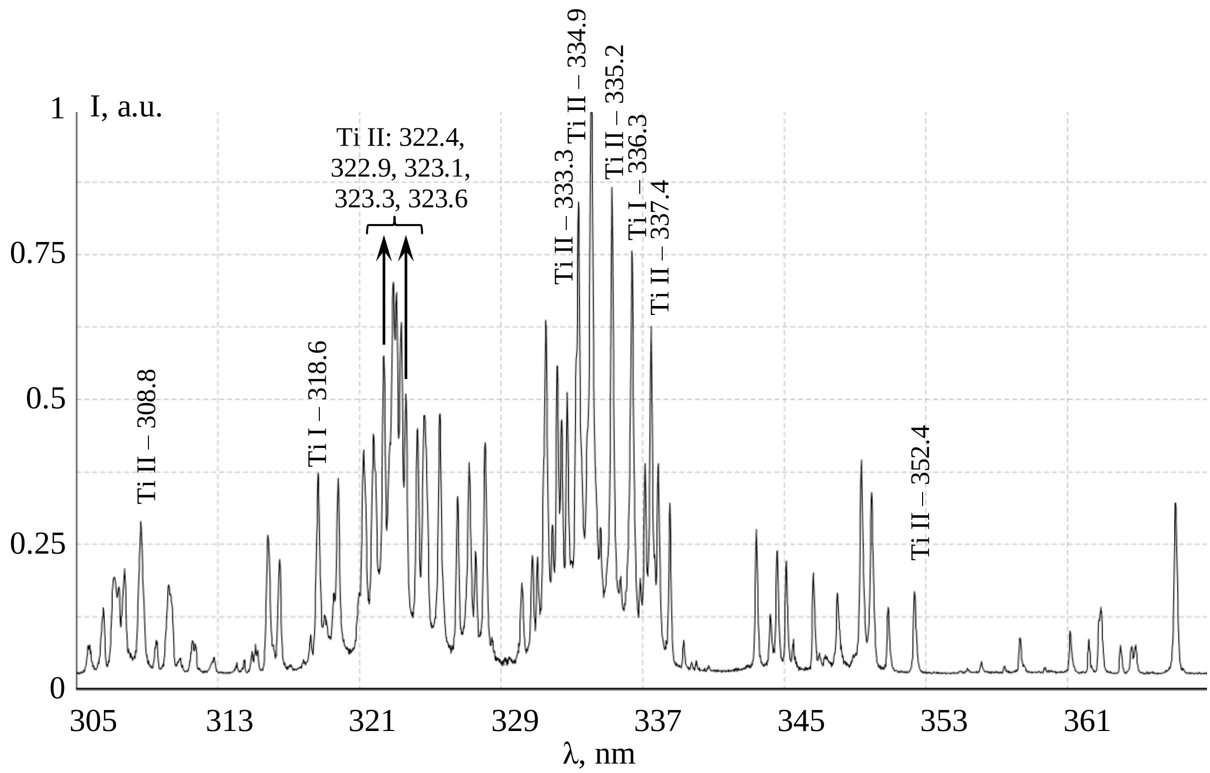

Figure 4. Part of the Ti laser plasma spectrum in the wavelength range of 305-372 nm

Pulsed laser plasma is significantly different from the plasma of magnetron discharge. Due to the high laser power density of $1.8x10^9$ W/cm^2, it increases the degree of plasma ionization. In laser plasma Ti II ion lines are the most intensive. Magnetron plasma has the greatest intensity of Ti I atomic lines.

We investigated influence of the delay between two laser pulses on the emission intensity of the laser plasma. Figure 5a shows the normalized intensity of individual spectral peaks that were recorded by means of the S100 spectrometer in the dependence on the delay in range from 0 to 5 μs. Figure 5b shows the same function for the individual spectral lines of Ti that were recorded by means of the monochromator with the CCD-line. The ratio of intensity at a specified delay between laser pulses to the intensity for simultaneous laser pulses was taken as the magnitude of the normalized intensity.

The time delay between pulses leads to significant increase of the plasma emission intensity. The maximum intensity reaches the value of 1.4-1.8 with the delay time of about 0.3-0.4 μs. The cause of the maximum intensity is most likely the peak of energy absorption of the second pulse by the plasma formed by the first laser pulse.

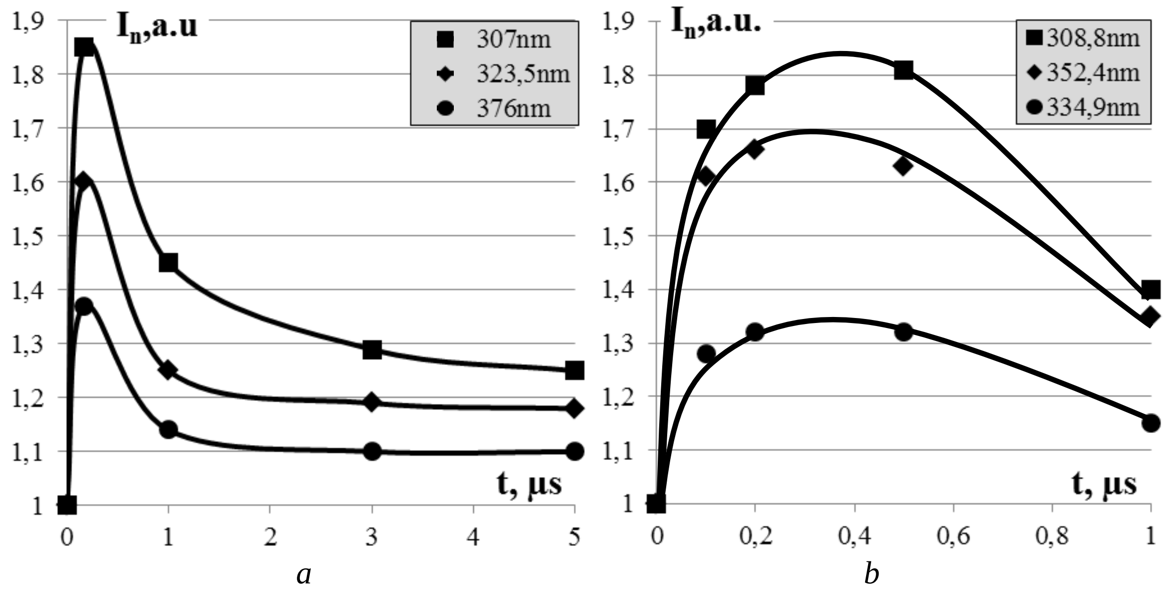

Figure 5. Spectral peaks intensity as a function of laser pulses delay

Conclusion

It was designed and created the experimental setup for the study of the combined plasma flow of various materials in gas at low pressure formed by magnetron sputtering and pulsed laser deposition. Investigation of laser plasma showed its significant degree of ionization. Two-pulse laser treatment increases the plasma radiation intensity to about 1.4-1.8 times and allows to control the concentration of ionic components in laser plasma at a fixed power density by means of setting the pulses delay.

References

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2. **Burmakou A.P., Kuleshov V.N.** Journal of Applied Spectroscopy, 74 (2007) 459- 463.