Study of Luminescence by Laser Induced Deposition Process for Materials with Different Buffer Gases and Pressure

Shatha S.M. Alazzawi
Baghdad University Physics department

Abstract

Study the fluorescence generated from the target surface of aluminum oxide, titanium dioxide when exposed to high luminescence intensity beam of carbon dioxide laser in atmosphere of oxygen and argon gases each one separately. We found that the intensity of the resulting fluorescence depend on the type and pressure of the gas surrounding the target in addition to the energy density of the laser beam.

Keywords: fluorescence, aluminum oxide, titanium dioxid.

1. INTRODUCTION

Laser induced chemical vapor deposition (LICVD) is a very important technology to develop a wide range of thin films and, crystals and electronic components, which are made of metal films, semiconductors and insulators [1-8]. This technique was used for the first time at the beginning of the seventies and since that time evolution be used not only in heating substrate or steaming the material, but in the dissociation of gas molecules [9-18]. The study of the conditions of the experiment other parameters is very important because they affect on the type of product in this modern way, by focusing the laser beam on the target, the interaction of laser with the target produces plasma above the target surface (Laser Produce Plasma) (LPP). This was an important topic of several studies because these characteristics of the plasma are of great importance in applications of (LICVD).

This research is studied the spectrum of the fluorescence emitted from the plasma medium in the existence of different gases (TiO\(_2\) and Al\(_2\)O\(_3\)) surrounding the target materials and also study the change of spectrum with changing pressure of the gases used [20], as well as the effect of changing laser energy on that. The formation of plasma depends on the medium in which the target present so if it is vacuum the plasma result from ionization of the steam of target material only. However, if the surrounding medium of target a gas, so besides plasma resulting from ionized metal, there is another plasma that resulting from ionization surrounding gas [20-25].

2. EXPERIMENT

Cell work is a cylindrical container locally manufactured material from stainless steel its length (8.3 cm) diameter (2.6 cm) has closed in both sides faced to laser beam by germanium window. The side window from which fluorescence passes, closed by glass that allows the passage of light in the region of (UV-VIS) and prevent the passage of wavelength (10.6 µ) for CO\(_2\) laser which occurs as a result of the dispersion of the target inside the cell, so that the laser beam falls perpendicularly on the target.

Connecting the work cell to a vacuum system through a differential valve so that the pressure inside the cell reaches \((0.76x10^{-4}\) Torr), the cell work is also connected to the adding gas by differential valve so that it can control the pressure of the gas accurately. Laser is focused on the sample studied by zinc solenoid lens (ZnSe) of focal length (10 cm) placed in front of a window in a specific position. Pulsed laser energy measured by energy scale (Joul Meter) of the company (LUMONICS Inc.) type (20D-253) this Joul Meter is one of the thermo - electric detector, which operates at room temperature to detect the incident laser with wavelengths within the infrared region (IR), and the maximum power that can be measured (15 J) response time (8 ms). The diameter of the aperture detector (4.6 cm) the Joul Meter connect with oscilloscope of the company (IWATSU) type (SS-5421).

TEACO\(_2\) laser used of the company (LUMONICS Inc.) type (920 L) transversal excitation at atmospheric pressure with good stability. Resonator of length (100 cm) consists of reflective mirror of gold – plated copper and high reflectivity (100 \%) and germanium mirror with reflectivity (60 \%) to get wavelength of (10.6 µ). Pulse duration of laser used is (100 ns) repetition (1 Hz) beam divergence (10 mR). It was use of gas mixture (12\% CO\(_2\), 14.3\% N\(_2\), 73\% He) to get energy of 3 J and less to almost 2 J as a result of many reason, including attenuation by mirrors, windows and lens used in the experiment, as well as the result of reflection from the surface of the target.

Generated fluorescence focused on the aperture detector by a quartz lens of focal length (4 cm). The resulting fluorescence represent the total amount of fluorescence occurring within a cell work. Specifications of the detector type (EG and G) is shown in Table 1.
Table 1 Detector EG and G Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Voltage</td>
<td>50 Volt</td>
</tr>
<tr>
<td>Rising Time</td>
<td>20 ns</td>
</tr>
<tr>
<td>Band Width</td>
<td>350 MHz</td>
</tr>
<tr>
<td>Responsivity</td>
<td>0.6 A/W</td>
</tr>
<tr>
<td>Series Resistance</td>
<td>1 KΩ</td>
</tr>
<tr>
<td>Peak Current</td>
<td>10 nA</td>
</tr>
<tr>
<td>Capacitance</td>
<td>8.5 pF</td>
</tr>
</tbody>
</table>

Detector circuit as shown in Figure 1.

![Detector Circuit Diagram]

**Figure 1** Schematic diagram of the electrical detector circuit used.

Detector has been connected with storage oscilloscope of company (IWATSU) type (TS-8123) and this in turn connects with X-Y recorder of company (KIPP and ZONEN) type (BD 90). Laser energy controlled by using cylindrical attenuation cell manufactured from material stainless steel of length (15 cm) and diameter of 3.5 cm and the cell closed from its two ended by germanium windows (Ge) (AR/AR) this cell connects to a vacuum system. Laser energy controlled by changing the pressure of (SF$_6$) gas which fills the cell as shown in Figure 2.

![SF$_6$ Gas Pressure Chart]

**Figure 2** Change of SF$_6$ gas inside the attenuation cell with the changing of emerging laser energy.

Gas pressure is controlled by differential valve. Pressure is measured by absolute gage of company (LYBOLD HERAES) measures the pressure in limits (1-200 Torr). This attenuation method is characterized than other used methods. Because of the shape of the intensity distribution of the outer laser beam is the same as the penetrating beam, unlike other methods, where the shape is cut and this will effect significantly on the calculation of brightness intensity. The reason for the use of (SF$_6$) gas inside the attenuation cell is that this gas has a strong absorption lines of most of the emission band (001-100) based on wavelength (10.6 µ) in CO$_2$ laser.

Figure 3 represents a diagram of the experiment devices.

![Experiment Devices Diagram]

**Figure 3** Schematic diagram for the experiment devices.
3. Results
We enter oxygen and argon gases each separately in a work cell when there is aluminum oxide (Al$_2$O$_3$) sample, or titanium dioxide (TiO$_2$) sample. We selected O$_2$ and Ar gases, on the basis that oxygen gas is a molecular gas and chemically active and has a susceptibility to oxidative and interaction with materials. Argon is an atomic inert gas, it does not react with substances. Both gases are transparent to CO$_2$ laser beam and do not have the ability to absorb laser beam. Different pressure has been used for the two gases where the pressure of O$_2$ gas is between 3x10$^{-1}$ and 4x10$^{-3}$ Torr and pressure of Ar gas is between 3x10$^{-1}$ and 7x10$^{-3}$.

We draw resulting fluorescence pulse as a result of inserting of the focused laser beam by lens on the samples used in a presence of gases under two different laser intensity, fluoridation in the presence of aluminum oxide at laser intensity 2.4 J increases gradually with the decrease in pressure of oxygen gas as in figure 4, but at the lowest intensity which is equal to 1.2 J the fluoridation was irregular with the decrease of oxygen pressure. The resulting fluorescence when introduction of Ar gas on aluminum oxide in the high intensity of the laser was decreased with the decrease of pressure as in figure 5. In the low intensity it was also irregular with the decrease of argon gas pressure. Figure 6 represents the high of fluorescence when introducing oxygen gas in a presence of titanium dioxide sample by two laser intensity equal to (1.2 – 2.6 J) the amount of fluorescence decreases gradually with decreasing pressure of oxygen gas, by introducing of argon gas on the same sample the amount of fluorescence when using high intensity of laser decreases gradually with the decrease of pressure, but in low intensity the fluorescence be irregular as in figure 7.

The ionization potential of argon gas higher than the ionization potential of oxygen gas, so the argon atoms surrounding the point of interaction of laser with the target needs to have high ionization energy, therefore will not absorb a high energy from laser in a form of expansion of the plasma so the argon gas can be considered more transparent than oxygen gas for the laser beam.

![Figure 4](image1.png) **Figure 4** Resulting fluorescence from the existence of oxygen gas around the sample of aluminium oxide in the work cell with the change of oxygen gas pressure

![Figure 5](image2.png) **Figure 5** Resulting fluorescence from the existence of argon gas around the sample of aluminium oxide in the work cell with the change of argon pressure

![Figure 6](image3.png) **Figure 6** Resulting fluorescence from the existence of oxygen gas around the sample of titanium oxide in the work cell with the change of argon gas pressure for two laser energy
4. Discussion
We have been put the analyzer line emission on (4779.5 Å) which related to the pack emission line of molecular (Al-O). We have obtained as a result of the opposite and expected with reference [20], where the emission intensity decreased with the presence of oxygen gas and decreased with increasing the pressure. This is expected and different to what was found by H. Sankur et al. reference [26]. While we found the situation reversed when adding argon gas was obtained with an increase in the emission with increasing the pressure of argon gas.

We observed that the presence of gases around the target interacts with plasma that produces as a result of the bombing of the target where the ionized that gas and ionization depends on the intensity of the light beam on the target where the higher gets the biggest ionization happen in the surrounding gas. Explanation of this case that the first part of the laser pulse vaporizes material from the target and generates plasma. The remaining of the pulse will be absorbed by the surrounding ionized gas in initially form by laser induced plasma. Thus breakdown occurs in the gas and ionization happen, but it is difficult to predict the operations that will occur accurately. In order to make sure that fluoridation is resulting from the interaction of the plasma produced from the target with the surrounding gas and not the absorption of the gas to the laser beam directly and breakdown in the gas happen, It has been removed the target and insert the laser beam so ionization or fluoridation not happen then we made sure that the fluorescence is generated by the interaction of the plasma formed from the target with the surrounding gas.

References


