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INVESTIGATION OF THE OPTICAL PROPERTIES OF THE G-C3N4 THIN FILM SYNTHESIZED FROM MELAMINE ORGANIC MASS

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Annotation. In this paper, the effect of the mass of the melamine precursor during the synthesis of a thin film of g-C3N4 on glass and silicon substrates was investigated using the method of pyrolytic decomposition of melamine with subsequent thermal polymerization. Optical measurements such as photoluminescence spectra, absorption spectra and transmission spectra were carried out in the article. The energy levels in the recombination process were detected by the Gauss analysis method and it was found that the decrease in energy peaks with an increase in the mass of melamine. And they also see a reduced absorption and an increased ability to penetrate in the wavelength range of 450-800 nm with an increase in the mass of melamine.

Ключевые слова: g-C_3N_4, photoluminescence spectrum, transmission spectrum, absorption spectrum, synthesis, melamine.

Graphite carbon nitride (g-C_3N_4) belongs to a new class of organic semiconductors. It is primarily composed of C and N atoms and is considered the most stable of the various forms of carbon nitrides. Due to its appropriate band gap (2.7 eV) and band edge positions, element content, low cost, and non-toxicity, g-C3N4 is used in various fields, such as photodegradation of organic pollutants, photoreduction, and photooxidation of water, photoreduction of CO2, electrocatalysis and fabrication sensors [1]. Two subdivisions have been proposed for g-CN. One of them is s-triazine (C_3N_3 aromatic ring), which is produced using the high-pressure molten salt method. The other is tri-s-triazine (aromatic ring C_6N_7). Thermal condensation of monomers (eg, melamine, cyandiamide, dicyandiamide, thiourea, and urea) always produces a defective g-C3N4 powder laid down in the last layer. After polyaddition and polycondensation at high temperatures, these monomers can form disordered g-C3N4 networks. Due to the different choice of precursors and processing temperatures, the optical and electronic properties of g-C3N4 can be easily tuned and the processing temperatures, the optical and electronic properties of g-CN can be easily tuned [2].

Methods for depositing g-CN films on solid substrates can be divided into two types: bottom-up and top-down approaches. Bottom-up methods include thermal vapor condensation (TVC), direct growth, microcontact printing, solvothermal method, and electrodeposition. Top-down methods include deposition of g-CN powders or nanolayers onto a substrate. The "bottom up" methods can provide tight contact between films and substrates. Even ultrasonic treatment cannot separate them from the substrate. In addition to the synthesis method, the chemical vapor deposition (CVD) method has also been used since then, has the advantages of controlling factors that affect the synthesis process of the g-C3N4 film, such as temperature, the flow rate of vapor passing through the tube or the mass of the precursor [3]. In addition to its recommended applications in the photocatalyst process, g-C_3N_4 material has many applications in optoelectronics or photovoltaic cells. To study and evaluate the advantages of the material in the field of optics, it has a simple and quick test, such as: photoluminescence spectrum, optical absorption spectrum or transmission spectrum.

Many papers have been published dealing with the study of the dependence of optical luminescence on temperature, pressure, or doping impurities in g-C_3N_4 synthesis. However, studies of the mass dependence of the precursor involved in the decomposition process and the formation of a thin film of g-C3N4 have not been carried out. In this study, we will elucidate the change in the crystal structure or optical parameters of a g-C_3N_4 thin film at different masses of the precursor.

To prepare films of graphite-like carbon nitride on various substrates, the process of pyrolytic decomposition of melamine followed by thermal polymerization is presented. Heat treatment was carried out in a quartz tube for 50 minutes at a fixed temperature of 600°C. The mass of melamine in the proposed experiment is 70, 130 and 400 mg. After the synthesis process, the quartz tube cooled naturally to a temperature close to room temperature. In this study, glass substrates (Glass), SiO_2/Si (Si_1), p^-/Si (Si_2) with a size of 10x10x2 mm were used. Figure 1 shows a diagram of the g-C_3N_4 thin film synthesis process.

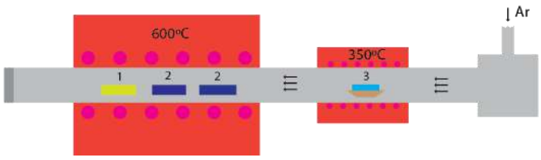

Figure 1 - Scheme for the synthesis of graphite-like carbon nitride using the method of heat treatment of melamine (3) on glass (1), silicon (2) substrates

The photoluminescence of g-C3N4 films on substrates was studied at room temperature under conditions of its excitation by monochromatic radiation with a wavelength of 345 nm, which was isolated from the emission spectrum of a 450 W xenon lamp using a Solar TII DM 160 monochromator. The photoluminescence spectrum was recorded with a Solar TII MS monochromator spectrograph 7504i. The radiation detector was a digital camera equipped with a Hamamatsu S7031 silicon CCD.

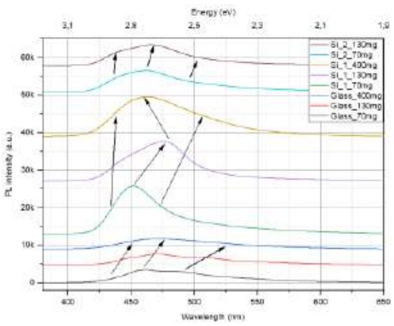

Figure 2 - PL spectra of a thin g-C3N4 film under different conditions of substrates and masses of melamine

From the results obtained in Figure 2, one can see the PL intensity is highest when g-C_3N_4 is on the Si_1 substrate, next to Si_2, and finally on the glass. The difference in the shape of the PL spectra is negligible as the mass of melamine changes, but you can still see how the peak energy shifts in the direction of increasing wavelength. To be able to clearly understand what change in the recombination process is taking place, it is necessary to analyze the spectra using the Gaussian method in the OriginPro software. The dependences of the energy of the peaks of the PL spectrum on the masses of melamine are shown in Fig. 3.

The recombination process of g-C_3N_4 differs when applied to different substrates. But it still includes two and three energy peaks to characterize the energy levels π^*-π, π^*-LP, σ^*-LP [4]. The peak energy decreases with increasing mass of melamine for the case of a glass substrate and Si_1; also, no such change was observed for Si_2. Especially with the appearance of unknown peaks on the glass substrate, when the mass of melamine is 70-130 mg, it is possible that these are impurities or the C3N4 layers are not yet sufficiently synthesized. To explain the existence of only two energy peaks at a melanin mass of 400mg and coating on the glass surface (Glass_400mg), it may be due to the influence of the interference effect, which usually occurs when increasing the thickness of a thin film on a substrate of other materials, increasing the ability to reflect excitation rays, which makes the results spectral analysis PL false.

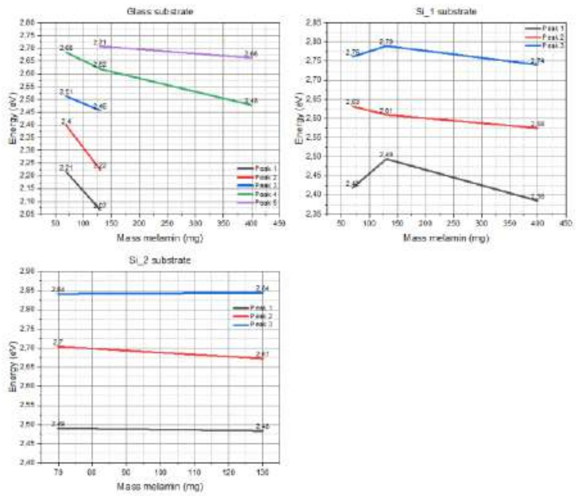

Figure 3 - Dependences of the energy of the peaks of the PL spectrum on the mass of melamine

The absorption spectrum and transmission spectrum of a thin film of g-C_3N_4 on a glass substrate were measured at various masses of melamine. One can see the difference in the decrease in absorption and increase in transmission with an increase in the mass of the melamine precursor in the wavelength range of 450–800 nm (1.55–2.76 eV). In addition, optical parameters such as refractive index n, energy band width and thin film thickness can be calculated. Figure 4 shows the transmission and absorption spectra of a thin film of g-C3N4 at different masses of melamine.

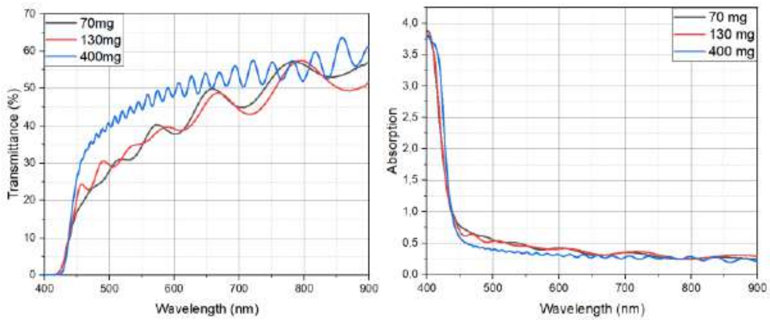

Figure 4 - Transmission and absorption spectra of a thin g-C3N4 film at different masses of melamine

Thus, a thin g-C_3N_4 film was synthesized on different substrates by pyrolytic decomposition of melamine followed by thermal polymerization. Photoluminescence spectra, absorption spectra, transmission spectra were measured with modern equipment. The obtained results show a clear effect of the mass of the melamine precursor on the quality of the optical structure of the g-C_3N_4 thin film. In this study, there are still several limitations associated with a clear analysis of optical parameters. The next study will continue to study the change in the optical parameter as well as structural changes in the bandgap from other factors such as temperature, annealing time, or other precursors.

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