

## EVALUATION

PhD thesis by Shoaib Mukhtar  
titled

**“Synthesis and characterization of visible-light-driven photocatalyst for  
degradation of organic pollutants”**

Water is essential for life on Earth, its importance is unquestionable. However, the growth of the world's population, coupled with accelerated industrial growth, has led to the release of large amount of harmful materials into the environment included the waters. Therefore, the removal of organic pollutants from water is a real problem, and much effort has already been made to solve it. The task gives many challenges; the photocatalytic implementation using visible light is a promising approach. Graphitic carbon nitride is a new and promising photocatalyst, the properties of which can be further improved by doping. Consequently, the topic of the dissertation is novel and important. The results have both of scientific and practical interest which is proved by the independent citations has already been obtained. (Scopus, 7th January 2026: <https://www.scopus.com/pages/citationOverview?authorsIds=58419837400&origin=AuthorNamesList>).

The PhD dissertation presents original research results in the field of photocatalysis. It is based on two publications in high-quality per reviewed journal (COLLOIDS AND SURFACES A: PHYSICOCHEMICAL AND ENGINEERING ASPECTS 705 p. 135739 Paper: 135739 (2025); MOLECULES 30: 2 Paper: 253, 28 p. (2025)) in which Shoaib Mukhtar is the first author. This meets the expectations of the Doctoral School of Chemistry and Environmental Sciences of University of Pannonia. The amount of the work is sufficient and the results are interesting. The reviewer is pleased that the structure and appearance of the dissertation have improved significantly compared to the form prepared for the pre-defense.

The 34-page “3. Literature review” chapter illustrated with 12 figures and supplemented with 13 reaction equations, contains 181 references. References used (all together 212) demonstrate the candidate’s proficiency in the literature. Candidate clearly presents the importance of the topic, outlines the efforts made so far to solve the problems. He compares in tables the literature results on the effect of solvent used for the solvothermal synthesis of g-C<sub>3</sub>N<sub>4</sub> and on the decomposition of para-nitrophenol under visible light. Furthermore, he summarizes the literature on the preparation of catalysts which led to development of his own novel catalysts in a tabular form, in a way that is easily comparable. The literary references are formally correct. Formulating the research objectives is clear and fits well to the literary trends.

The experimental methods were carefully selected. It is noteworthy that, to address an environmental problem, Candidate used environmentally friendly materials (cardamom seeds, starch) for catalyst preparation. The photocatalytic measurements

were well planned and carried out carefully. From the behavior of the appropriately chosen model compounds, by means of the knowledge of the literature data, it was possible to deduce the mechanism of the reactions taking place on the photocatalysts. I found measurements on catalyst recycling also important. The chosen physicochemical characterization methods, which included the most modern ones, were well suited for the analysis of the newly prepared samples. These measurements covered a wide range of testing, thereby revealing a wide range of properties, which greatly contributed to the understanding of the behavior of catalysts.

Chapter "5. Results and discussion" is divided into 3 main subsections according to the preparation of the base g-C<sub>3</sub>N<sub>4</sub> and the two modified ones. It follows more or less the structure of the two own publications. The conclusions drawn from a large number of experiments are correct. There are a short conclusion-subsection at the end of the subsections.

The dissertation is written in a good style; its structure is logic. It contains almost no grammatical or spelling errors. Minor mistakes: the COU abbreviation (Table 5.5, page 67) is not given in the text and is not listed at the beginning of the dissertation; Figures 5.14 and 5.15 are referred (page 70) before the mentioning of Figure 5.13 (page 74); caption of Figure A5.6 in the Attachment is shifted far from the figure itself (page 153), etc. Perhaps the sentence "This pattern strongly indicates that Bi<sub>2</sub>S<sub>3</sub>/Bi<sub>2</sub>O<sub>3</sub> predominantly resides on the surface of these composites rather than being homogeneously distributed" (page 99) is more correct in "homogeneously distributed in the bulk". The figures and tables in the dissertation are clear and informative. The appearance of the dissertation is attractive. The "6. Summary" is well written as well as the booklet.

### Notes and questions about the content

1. It is written (page 57): „Energy-dispersive X-ray spectroscopy (EDS) (Figure 5.3) confirmed that pristine g-C<sub>3</sub>N<sub>4</sub> contains approximately 42.9 % carbon and 57.1 % nitrogen” - **How these values were obtained?**
2. Regarding the chemical state of the silver in the Ag-g-C<sub>3</sub>N<sub>4</sub> nanocomposites, the following sentence can be found (page 80): „...the Ag 3d spectrum (Figure 5.17/d) shows two spin-orbit split peaks at 368.3 and 368.4 eV, corresponding to the Ag 3d<sub>5/2</sub> and 3d<sub>3/2</sub> levels of metallic silver, as reported in the literature [197]”. However, the cited work wrote: “Fig. 7B shows Ag 3d spectrum which could be resolved into two peaks (3d<sub>5/2</sub> and 3d<sub>3/2</sub>) due to the spin-orbit coupling with binding energies of 368.21 and 374.17 eV, respectively. These binding energy components are attributed to metallic silver ...”[O. J. Achadu, I. Uddin, and T. Nyokong, “The interaction between graphene quantum dots grafted with polyethyleneimine and Au@Ag nanoparticles: Application as a fluorescence ‘turn-on’ nanoprobe,” *Journal of Photochemistry and Photobiology A: Chemistry*, vol. 324, 2016, doi: 10.1016/j.jphotochem.2016.03.016] - **What is the reason of the difference?** Furthermore, according to explanation of XPS result the surface of Ag-g-C<sub>3</sub>N<sub>4</sub> nanocomposites can be described by metallic silver but the following conclusion is written in 5.2.6. subsection: “Uniformly embedded silver nanoparticles within the g-C<sub>3</sub>N<sub>4</sub> network, together with dispersed silver ions, enhance light absorption and promote effective separation of electron-hole pairs, resulting in superior photocatalytic performance” (page 81) - **How can this contradiction be resolved?**

3. **Which results prove the occurrence of the surface plasmon resonance in case of the silver containing catalysts prepared?**
4. Catalyst samples were characterized physical-chemical methods (Figure 5.15, Table 5.7, etc.) after UV or visible light irradiations. **Were these recovered samples from photocatalytic reaction?** If not, is there some knowledge about the changes of the catalysts during a real photocatalytic conditions?
5. **To the Candidate's knowledge, is g-C<sub>3</sub>N<sub>4</sub> /modified g-C<sub>3</sub>N<sub>4</sub> already used in practice (processes, patents, etc.)?**

Candidate summarizes his scientific results in five thesis points. I accept the thesis points as new scientific results. I consider the most important result of this work to be the development of new types of catalysts that are also effective in visible light. **I accept the dissertation** and after successful doctoral defense I recommend that the Candidate is awarded the PhD degree.

Budapest, January 09, 2026



Emília Tálas  
PhD, senior research fellow  
Institute of Materials and Environmental Chemistry,  
HUN-REN Research Centre for Natural Sciences