COST EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA20129

Grantee name: Ilaha V. Izatova

Details of the STSM

Title: Amorphous transformations and structural evolution of nanocrystalline zinc oxide particles under irradiation environments

Start and end date: 02/02/2025 to 28/02/2025

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

To confirm the purity of the ZnO nanopowder, k_0-Instrumental Neutron Activation Analysis (k_0-INAA) and X-ray Diffraction (XRD) techniques were used. These techniques helped determine elemental composition and structural integrity before neutron irradiation. The samples were carefully prepared, sealed in polyethylene ampoules, and labeled for controlled exposure to neutron flux in subsequent experiments. The TRIGA Mark II light-water pool-type reactor served as the neutron source for the irradiation experiments. The ZnO nanopowder samples were divided into four groups, each exposed to a different neutron dose to study dose-dependent effects on the nanoparticles. The neutron doses applied were: 1.6×10^{15} n/cm², 8×10^{15} n/cm², 4×10^{16} n/cm² and 2×10^{17} n/cm². These neutron exposure levels were selected to observe how increasing neutron fluence influences the structural, chemical, and electronic properties of ZnO nanoparticles. For the determination of short-lived radionuclides, approximately 0.05 g of ZnO nanopowder was sealed in a pure polyethylene ampoule. The sample, along with the Al-0.1%Au (IRMM-530R) standard, was stacked in a polyethylene vial using a sandwich configuration to ensure accurate comparative analysis. The samples were irradiated for 5 minutes in the carousel facility (CF) of the TRIGA reactor at a thermal neutron flux of 1.1×10^{12} n/cm²s. After irradiation, the gamma radiation emitted by the sample was measured at different cooling intervals using an HPGe detector (45% relative efficiency): To investigate long-lived radionuclides, the same preparation method was used, and the sample was irradiated for a longer duration (12 hours) in the carousel facility of the TRIGA reactor. The measurements were taken at three different cooling intervals to observe long-term decay patterns and transmutation effects: Following the completion of neutron irradiation experiments, the samples were subjected to continuous neutron flux for up to seven hours under controlled conditions to assess their long-term stability and resistance to radiation-induced changes. Once the purity of the ZnO nanoparticles was verified, they were subjected to neutron irradiation to study transmutation effects.

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

During neutron interaction, ZnO undergoes transmutation processes that can lead to elemental changes or defect formation in the crystal lattice. This study aimed to investigate how neutron exposure alters the physicochemical properties of ZnO nanoparticles. To analyze the effects of neutron irradiation, several advanced characterization techniques were employed: HRTEM used to examine nanoscale structural changes, defect formations, and morphological modifications resulting from neutron interactions. XRD conducted before and after neutron irradiation to detect any phase transitions or structural deformations. This STSM successfully explored the effects of neutron transmutation on high-purity ZnO nanoparticles. All collected data were systematically analyzed to understand the influence of neutron transmutation on ZnO nanoparticles. Comparisons between pre- and post-irradiation samples provided insights into radiation-induced effects such as: Structural defects (e.g., vacancy formation, interstitial defects), crystalline phase stability and changes in electronic and optical properties. The results obtained from this study will contribute to a broader understanding of neutron transmutation in ZnO nanoparticles and may have potential applications in radiation-resistant materials, nuclear technology, and advanced semiconductor devices. Further studies will focus on optical and thermal property evaluations to extend the scope of this research.

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

The STSM successfully met its objectives, making significant contributions to the MultiChem COST Action, particularly in the study of radiation-induced alterations of nanostructures. The key achievements include: Successful neutron irradiation of ZnO nanoparticles, enabling a detailed study of transmutation effects and detection of radiation-induced structural changes, including the formation of defects and lattice distortions. These findings directly contribute to Working Group 1 (WG1, Task T1.4) by improving the understanding of how nanoparticle structure and composition influence their radiosensitizing properties. Moreover, the results support Working Group 4 (WG4, Task T4.3) by advancing the dissemination of new insights into neutron-modified nanomaterials. The study's anticipated impact extends beyond fundamental research, as it lays the foundation for potential applications in radiation shielding, sensor technologies, and biomedical nanotechnology. The STSM has provided significant benefits to both the MultiChem COST Action and the applicant. By exploring radiation-induced changes in ZnO nanoparticles, the research directly aligns with the MultiChem objectives of advancing radiation-modified nanomaterials. The study contributes to the development of materials with enhanced radiation resistance, which is of great interest in fields such as nuclear technology, materials science, and nanomedicine.

For the applicant, this STSM has been an essential step in building an international research career in nanophysics and materials science. The opportunity to work with advanced neutron irradiation techniques and state-of-the-art characterization tools has provided valuable hands-on experience. This experience will be crucial for future studies and collaborative projects within the EU research framework. Furthermore, the scientific networking opportunities gained during the STSM have opened doors for potential research partnerships and joint projects with leading experts in radiation physics and nanotechnology. To build upon the findings of this STSM, several follow-up activities are planned: The experimental results will be compiled into a research article for submission to a high-impact journal in the fields of nanomaterials and radiation physics. The research findings will be presented at international conferences and workshops, contributing to the scientific visibility of the MultiChem COST Action. Future experiments will involve higher neutron fluences and longer exposure durations to further investigate radiation-induced effects. This STSM has been highly successful in achieving its research objectives while strengthening scientific collaboration, knowledge exchange, and professional development. The study of neutron transmutation effects on ZnO nanoparticles has provided valuable insights into radiation-induced defect formation, structural changes, and transmutation processes.

The planned follow-up activities will ensure further dissemination of the findings, contributing to the broader MultiChem COST Action objectives. With new collaborations and research extensions in progress, the impact of this STSM will continue to grow, supporting both fundamental science and applied nanotechnology. This work represents a crucial step in advancing radiation-modified materials research, paving the way for future innovations in nanophysics, materials science, and nuclear applications.