Raman Spectroscopy Studies of TRISO-Particle Fuel

Zuzanna M Krajewska, and W Gudowski
National Centre for Nuclear Researchul. Andrzeja Sołtana 7 Otwock, Świerk 05-400 Poland
phone: +48 792525066, email: zuzanna.krajewska@ncbj.gov.pl

Abstract. Development of High Temperature Gas-cooled Reactors opens new horizons for nuclear power in Poland. Good understanding of the failure-free performance of Tri-structural ISOTropic (TRISO)-particle fuel is a key for the safe and efficient operation of those reactors. It is also essential to avoid potential errors in TRISO fuel production for the HTR program in Poland. In a longer perspective to ensure the highest possible quality of the TRISO fuel fabrication and storage before loading into the reactor core, it is necessary to control the quality of the TRISO-particle fuel in order to understand the aging of fresh fuel. Nevertheless, such a solution requires to determine whether the passage of time affects the occurrence of changes in TRISO fuel layer’s structure and at the same time whether it contributes to increasing the probability of damage to the examined fuel material. For this purpose, it is planned to perform an experiment on different types of TRISO fuel, produced in different periods of time. The comparative analysis will be based mainly on the experimental method of Raman spectroscopy.

1. Introduction
Poland does not have at present any nuclear power plants in spite of the fact that the development of nuclear technology started already in mid the 50s of the last century. In 1955 the nuclear research institute was established in Świerk, in the outskirts of the capital city Warszawa. The primary mission for this institute was the development of nuclear technology and neutron physics around the first Polish research reactor EWA. Today this institute is called the National Centre for Nuclear Research (NCBJ) in Otwock-Swierk and continues its research mission with the MARIA research reactor a successor of reactor EWA.

The first attempt to construct a nuclear power plant in Poland took place in the 1980s with the usage of the technology of the VVER-440 type nuclear reactor at Żarnowiec site, close to the Baltic city Gdańsk. However, the impact of the Chernobyl accident in 1986 and then dramatic political transformations in Poland and other Central European countries caused the construction of the reactor first to stop and then the project to be completely abandoned. Suspended for years, the plan for the construction of the Polish nuclear power plant was reopened in the 2000s. The current program called the Polish Nuclear Power Program (PPEJ) was approved by the government in 2014 and updated in 2020. The objective of the PPEJ program is to construct and commission a Generation III+ nuclear power plants with a pressurized water reactor (PWR) type of a total installed nuclear capacity between 6 and 9 GWe [1].

The PPEJ program envisions also the construction of high-temperature gas cooled (HTGR) research reactor at NCBJ. HTGR research reactor under development at NCBJ is a Generation-IV (Gen-IV) reactor type, with a graphite-moderated, helium-cooled core fueled with uranium TRISO
type fuel. Gen-IV is a common name for ongoing research projects of future-oriented different nuclear reactor concepts. The basic features to be met by those reactors are safety, reliability, efficiency, and low production costs. HTGR type of reactor provides several inherent safety advantages due to specific design features, physical laws, and due to reactor materials behavior, such as low-power density in the reactor core, a large heat capacity of the core, and an inert coolant that can mitigate severe accidental consequences during loss-of-coolant accident scenarios. Due to these specific features and due excellent performance of the TRISO based nuclear fuel the high temperature reactor has been recognized as an inherently safe reactor type.

Historically, two concepts of the HTGR have been developed, the pebble-bed (Figure 1) and the prismatic core design (Figure 2):

- The pebble-bed concept is based on spherical fuel elements with 60 mm diameter piled in a reactor vessel. The pebble fuel element consists of an inner 50 mm diameter fuel zone surrounded by a 5 mm thick fuel-free shell of the graphitized fuel matrix material. The fuel zone contains the coated particles, overcoated with the matrix material, and then homogeneously dispersed within the graphitized matrix [2]. The pebble-bed pilot reactor installation was built at Jülich, Germany in the 1960s, and two such reactors are currently in the final stage of commissioning at Shidaowan in China [3,4].

![Figure 1. Pebble bed design of the HTGR [4].](image1)

- The prismatic core includes hexagonal shape blocks with circa 800 mm high and circa 360 mm across flats, fabricated from graphite. In the graphite block, separate fuel and coolant holes are drilled. Cylindrical fuel compacts with circa 12.5 mm of diameter and circa 50 mm long (contain the over-coated fuel particle), are stacked in the fuel channels [5]. The pilot prismatic HTGRs were constructed by General Atomics at Peach Bottom and Fort St. Vrain in the USA [3,4].

Both concepts of the HTGR reactor are based on TRISO particle fuel.

![Figure 2. Prismatic design of the HTGR [6].](image2)
It is assumed that the first industrial HTGR type of reactor will be constructed in Poland around 2040. Until then it is planned to construct an HTGR research reactor at NCBJ. Both for the research reactor project and for the industrial reactor project an important issue is to acquire TRISO-particle fuel. TRISO fuel can be either manufactured in Poland or can be purchased from external suppliers. The second option seems to be today a more advantageous alternative. The TRISO fuel purchase from politically and economically reliable countries will ensure at least at the first stage a secure supply of this fuel for HTGR reactors.

This publication highlights the necessity of quality control of TRISO fuel in order to understand well aging of fresh TRISO fuel and in a longer perspective to ensure the highest possible quality of the fuel fabrication and storage before loading into the reactor core. The rationale for such an action is not only economic but also increasingly stringent climate and environmental requirements. Therefore, it seems necessary to determine whether the passage of time has an impact on the occurrence of the changes in the structure of TRISO fuel layers and at the same time whether it contributes to increasing the probability of damage in the fuel material under investigation.

The research on TRISO-particle fuel would focus on examining the quality of freshly manufactured fuel and degradation processes of the fuel before entering the reactor core. We call this process a front-end investigation of TRISO fuel.

For this purpose, the Raman spectroscopy measurements are planned. The results of these experiments will also help serve as the preliminary stage to establish a laboratory for TRISO fuel quality control and assessments. It would also be a prelude to constructing a TRISO fuel production line in Poland or Europe.

2. Experiment
The experiment aims to check the TRISO fuel particle for damage occurrence, through the Raman method of spectroscopy. Moreover, this experiment aims to conduct research on different types of TRISO fuel, produced in different periods of time, and to check the aging effects of the layers in the tested TRISO fuel particles. The experiment includes measurements on TRISO fuel currently produced (e.g., in 2020) by one of the leading companies, e.g., X-energy, and measurements on TRISO fuel produced several decades earlier (e.g., in 2000), e.g., on German fuel which has been stored. In the experiment, both surrogates and TRISO particles with uranium kernel will be measured. The results obtained from the measurements on both types of particles will be compared based on the Raman spectra.

The experiment will be conducted in two stages:
- Stage 1 - analysis of the intact "virgin" sample (front-end);
- Stage 2 - analysis of the sample after ion implantation. Ion implantation will at that stage simulate the processes of irradiation of the TRISO particles in the MARIA reactor.

The ion-beam irradiation technique is used to imitate the neutron irradiation process because it allows investigating the occurrence of damage caused by irradiation without the necessity to deal with radioactive materials and occurs in a relatively short time. The differences between neutron irradiation and ion implantation are energy (ions have smaller energies [keV] than neutrons [~ 2 MeV in fission system]) [7], charge (neutrons have no charge), and size. The size of the colliding particle is much larger compared to the size of the neutron. The disadvantage of ion implantation is that, even if high fluence can be achieved in a short time, the depth of penetration of the sample is shallow. Typically, ion implantation is with noble-gas ions like Ar⁺, He⁺, Xe⁺, Ne⁺, and Kr⁺. The irradiation of the sample is performed using different ions and ion energy [8-16]. To perform the experiment on the intact samples, ion irradiation with He⁺ ions, with a fluence between 10¹² and 10¹⁷ ions/cm² is assumed.

The preparation of the whole experiment will therefore be based on five parts:
- The preparation of the TRISO sample for examination;
- Verification of the consistency of the original TRISO sample with production data, by using the Raman spectroscopy method;
- Ion implantation on a TRISO sample;
- Revision of the TRISO sample, after ion irradiation, using the Raman spectroscopy method;
- Comparison of the results.

The following factors should be taken into account before starting the experiment:
- TRISO technical data;
- Raman spectroscopy method.

2.1. TRISO-coated particle
TRISO fuel production has been developing for more than six decades, during which the fuel has been modified, tested, and improved to achieve the lowest possible degree of damage of the TRISO sample. TRISO fuel consists of uranium kernel, coated with four layers of pyrocarbon and silicon carbide and it confines fission products even at the temperature of 1600 deg C [6].

Each TRISO particle (Figure 3) consists of:
- Kernel - surrounded by four different coating layers of pyrocarbon and silicon carbide;
- Porous pyrocarbon buffer layer (PyC) - first layer surrounded the kernel.
- Highly isotropic inner pyrocarbon layer (IPyC);
- Silicon carbide (SiC) layer;
- Outer pyrocarbon layer (OPyC).

![Figure 3. TRISO fuel cross-section [17].](image)

The TRISO-coated particles have an overall diameter in the range of 500 to 1000 μm [18]. Each layer has the following dimensions [19]:
- The fuel kernel with the diameter in the range of 350-600 μm. The optimal kernel diameter is a function of enrichment and burn-up limits - with higher enrichment and burn-up designs - smaller diameter;
- Porous pyrocarbon buffer layer thickness is in the range of 90 to 100 μm;
- The IPyC layer thickness is typically in the range of 35 to 40 μm;
- The thickness of the SiC layer is around 35 μm;
- The OPyC layer thickness is typically in the range of 35 to 40 μm.

Many experiences with manufacturing coated-particle fuel have demonstrated the feasibility of producing large quantities of TRISO fuel with simultaneous low defect level which approaching defect fractions of $10^{-5}$ [19]. During irradiation partial or complete failure of the TRISO particle may occur, caused by some failure mechanisms. Fuel failure mechanisms can be categorized. Each author has his own way of dividing the damages, however, the most general division concern mechanical and chemical failures.
The TRISO fuel failure mechanisms have been divided according to two categories:

- **Damage location** - TRISO fuel failure can be considered in terms of damage location, distinguishing as the external and internal area of the particle. External damage to TRISO structure usually occurs as a result of some physical force and is created mainly during the production process of these particles. The internal damages can be observed on the surface of each layer or at the joint point of these layers. These failures are mainly caused by mechanical or chemical factors;

- **Damage factor** - There are two types of factors causing damage in TRISO fuel particles, mechanical and chemical. Mechanical failures can appear in each of the structural layers, like in a buffer, IPyC, SiC, and OPyC layer. They arise as a result of the deformation of the layers due to their mutual interactions. A layer may be damaged by the initiation and propagation of a crack or by stress or friction which exceeds the strength criterion of the material. Chemical failures can also exist in each of the TRISO layers. That kind of damage is caused by the interaction of chemical elements and by the presence of fission products that accumulate inside the particle during irradiation.

Our experiment will focus on mechanical failures.

The TRISO fuel can be characterized before and after irradiation to see how the particle has been evolved. It is assumed that two types of TRISO fuel will be used for the experiment, different in terms of year of production as well as place and method of manufacture. Therefore, it seems necessary to determine whether the passage of time has an impact on the occurrence of the changes in the structure of TRISO fuel layers and at the same time whether it contributes to increasing the probability of damage in the fuel material under investigation. Therefore, three stages of the TRISO particle investigation can be defined: front-end (understood as testing the TRISO particle before it is placed in the reactor), irradiation in the reactor core, and post-irradiation examination.

Because the irradiation in the reactor core is a long-term process, to predict the behavior of TRISO fuel particle in a shorter time, ion implantation can be used. This method reflects the irradiation process placed in a reactor. Modeling of irradiation with ion implantation is understood as monitoring the TRISO particle during the irradiation process in the reactor.

### 2.2. Raman spectroscopy method

The most popular diagnostic methods for the TRISO coated-particle include:

- Scanning electron microscopy (SEM) to observe microstructural features;
- X-ray diffraction (XRD) for crystal structure analysis;
- Nanoindentation for the hardness and modulus Young of each layer;
- Crush test to improve the fracture strength;
- Raman spectroscopy for sample characterization.

In our experiment, Raman spectroscopy was selected as a screening research method for monitoring the changes in spectra, in “virgin” and an ion-irradiated sample of both TRISO fuel particles.

Raman micro-spectroscope is a device for recording Raman scattering spectra. Raman scattering spectra show elements characteristic for substances present in the tested sample, taking the form of bands. These spectra are used to analyze the composition of the test sample or to analyze the chemical components and their location in the sample. Raman spectroscopy makes use of the fact that the Raman scattering spectrum is excited in the visible, near-infrared, or ultraviolet region. This Raman spectrum is an oscillation-rotational spectrum because it provides information about oscillational and rotational energy levels of molecules and it record spectra of the tested molecule. Each molecule is characterized by the number of vibrations, their frequency and amplitude. Raman scattering spectrum showing bands with characteristic contours and position is a reflection of the vibration potential of a given molecule. In this Raman spectrum, one can well observe the symmetrical vibrations of the molecule, vibrations of the carbon skeleton of the molecule, and vibrations between atoms with double and triple bonds [20,21].
The characteristic shape of the Raman spectrum is in the form of the bell curve, which is a feature of the interaction of substances with radiation. The contour of the bell curve band is defined as the dependence of the intensity of the amplitude (I) of absorption, emission, or scattering on the frequency (ν) of radiation interacting with the system. The main parameters characterizing the band is:

- **Half-width** (Δν₁/₂) - this is the width of the band contour, determined in the middle of its height,
- **Frequency** (ν₀) - it is a value corresponding to the maximum height of the contour of the tested band,
- **Intensity** (Iₘₐₓ) - this is the height of the band contour measured from the background level,
- **Integral intensity** (I∞) - this is the area bounded by the band contour and the background [22,23].

Raman spectroscopy is an efficient, non-destructive, non-contacting, and quick measurement method to characterize the structure of graphitic materials, in particular providing valuable information about defects and in-plane crystallite size. It provides a fingerprint to identify the chemical component, to analyze them, and to better understand their structures.

The use of Raman spectroscopy to analyze the TRISO particle is one of the methods to show the changes in fuel structure as a result of irradiation. Using this method, we can observe, among others, damage appearing in the TRISO particle (layer cracks) and determine the concentration of carbon in each layer. By measuring the particles before and after irradiation, we can compare the changes that have occurred as a result of irradiation in the reactor.

2.3. **TRISO-particle fuel measurement by Raman spectroscopy method**

As was mentioned above the experiment aims to analyze the TRISO fuel particles using the Raman spectroscopy method, in two steps, analysis of virgin sample and sample after ion irradiation. This means that on both stages, each of the TRISO layers will be explored in terms of chemical content. As a result, the Raman spectrum representing the chemical composition of each layer will be resented. Based on the obtained Raman spectra, the results from the measurements will be compared.

The presented TRISO sample analysis process will be carried out for TRISO samples produced at different time periods. The experiment will include the measurements of TRISO fuel currently produced and TRISO fuel produced several decades ago. In both cases, the experiment will start with sample preparation by polishing. The TRISO sample is polished to obtain the cross-section of the sample. The polishing process will use abrasive paper of different grit sizes from 300-2000 [12,14,24,25].

The TRISO sample, after polishing, is placed under the Raman spectroscope and subjected to the point, and linear measurements to visualize an average spectrum obtained for each layer of the TRISO sample, and the so-called map surface, which will cover the area from the kernel to the end of the OPyC layer, is measured.

The TRISO particle layers like buffer, IPyC, and OPyC are based on pyrolytic carbon. Pyrolytic carbon is a material similar to graphite. For these reasons, the graphite spectrum is the starting point for TRISO analysis by Raman spectroscopy (Figure 4).

![Figure 4. Raman spectrum of virgin nuclear graphite [8].](image-url)
Raman spectra of the carbon materials are constructed with two characteristic bands, G-band mainly at position 1580 cm\(^{-1}\) and D-band at position 1355 cm\(^{-1}\) [11]. Fully or single crystalline graphite shows only G-band. D-band appears by the introduction of defects in graphite, like disordering of the basal plane. That is why D comes from disorder. The Raman spectra of all carbons show bands in the region of 800-2000 cm\(^{-1}\) [26]. The vibrations of two carbon atoms linked by strong double bonds (C=C) find at the position around 1600 cm\(^{-1}\) [27]. The first order band, the “G” is due to the bond stretching of all pairs of sp\(^2\) atoms in both rings and chains. There are also three bands designed as “D” modes, called: “D\(_1\)” (1346 cm\(^{-1}\)), “D\(_2\)” (1367 cm\(^{-1}\)) and “D\(_3\)” (1622 cm\(^{-1}\)) [7]. These “D” modes are attributed to the disorder in the graphitic structure and due to the breathing modes of sp\(^2\) atoms in rings, their positions are not always at the same point.

To the first stage of our experiment the TRISO-particle fuel samples so-called “ZP12” were used. Those surrogate samples were produced by the French Alternative Energies and Atomic Energy Commission (CEA) in 2001 for a research project HTR-F/F1 [28]. Measurements on TRISO samples are taken with a Renishaw Raman spectroscope, and the spectra are collected by focusing a laser \(\lambda = 785\) nm wavelength.

After polishing the samples, the following measurements were performed:

- **Point measurements** – The point measurement of a sample involves taking a measurement, i.e., collecting a spectrum, at an arbitrarily selected location from the entire cross-section of the sample. Several measurement collection locations are selected for each TRISO layer. The point measurements are intended to illustrate the averaged spectrum obtained for each layer of the sample under investigation. In the case of the TRISO ZP12 sample analyzed, it can be seen that this particle consists of a kernel and only one covering layer. As shown in Figure 5, the ZP12 sample contains a kernel with zirconium dioxide and a covering layer, probably a buffer, consisting of two characteristic bands “D” and “G”;

![Figure 5](image)

**Figure 5.** The average Raman spectra obtained for the ZP12 sample from point measurements [own data].

- **Linear measurement** – A linear measurement involves collecting Raman spectra along a single line, starting from the kernel to the end of the last covering layer. This measurement results in information about how the spectra change over successive layers of the TRISO sample. For the TRISO sample ZP12 (Figure 6), Raman spectra were recorded over a length of 100 \(\mu m\) with a step of 2 \(\mu m\).
Surface map – Performing a surface map measurement involves selecting an area of the sample that includes all layers of the TRISO sample. In a given area, Raman spectra are collected. The goal of the measurement is to obtain a large amount of data from the collected spectra, from which parameters such as band position, half-width, and the ratio of the intensity of D- Raman band and G- Raman band (ID/IG) can be described. The intensity of the occurrence of a parameter in the analyzed sample area can then be visualized. As an example of a surface map, the concentration of parameters such as the position of the G and D bands is shown in Figure 7.

Figure 6. Example of the linear measurement through sample ZP12 containing one layer. [own data].

Figure 7. Raman surface map of the ZP12 sample with a concentration of the G-band and D-band [own data].
These results were obtained for a TRISO fuel particle consisting of only one layer. For these reasons, further experimental work will not be continued on the ZP12 particle. Currently, we are looking for a TRISO fuel consisting of a kernel and four covering layers for further experiment.

The expected results for the surface map measurements for the TRISO particle fuel with five layers is shown in Figure 8. Based on the obtained Raman spectra, it is possible to create a map showing the occurrence of a given chemical element in the analyzed structure. In the case of TRISO, the map shows the selected area which has been measured using the Raman spectroscope. The result of the measurement is that TRISO in each layer is based on carbon. To differentiate the TRISO layers, a selection of different colors was used. A given color represents the intensity of a given spectrum, the most similar spectra represent the same layer.

![Figure 8. The map of TRISO structure made by Raman spectroscopy [29].](image)

After the initial measurement of the TRISO sample by the Raman spectroscopy technique, the sample will be treated with ion irradiation with He\(^+\) ions, with a fluence between $10^{12}$ and $10^{17}$ ions/cm\(^2\). Afterward, the sample will be placed under the Raman spectroscope again and the measurements will be taken in the same area of the tested sample. Since the ion implantation is to reflect the TRISO fuel irradiation in the reactor, it is expected that after the implantation it will be possible to observe the changes that occurred in each layer of the sample. It is therefore assumed that the analysis of the parameters obtained before and after the ion implantation, will reveal significant changes in the values of the indicated parameters and will be depicted in the shape of the received spectrum. Raman analysis shows that the “D” and “G” bands for implemented samples are broadened. It is assumed that a change in the appearance of the spectrum in the G- and D-band positions will show us the degree of damage to the sample. Figure 9 presents an example of a graph of spectrum changes before and after ion irradiation [9].
Figure 9. Comparison of Raman spectra of the non-irradiated rear surface and the front surface exposed to H plasma [9].

The results will allow observing differences in the Raman spectrum obtained for both types of TRISO fuel particles. Conclusions based on Raman spectrometer measurement will be used to determine whether the passage of time affects the degree of damage that occurred to the analyzed samples.

The results obtained from the experiment are a prerequisite to designing a production line and, above all, to create a laboratory for quality control and preliminary analysis of TRISO fuel, both those currently produced and those that have been or will be stored.

3. TRISO Laboratory – Building Up Competence and Excellence for The HTGR Program in Poland

A mission for a TRISO Laboratory at NCBJ would be, at least, three-fold:

- Development of quality control (QC) and quality assessment (QA) methods to prove for the Polish regulatory body that TRISO fuel performance is adequate and complies with safety regulations. This part of the mission will be focused on unirradiated TRISO fuel, i.e., on the front-end of the HTGR nuclear fuel cycle;
- Irradiation of the TRISO fuel under very well controlled conditions in MARIA reactor and then post-irradiation examinations (PIE) of TRISO fuel;
- Investigations of irradiated TRISO fuel with a focus on its performance as a spent fuel/waste for the final disposal. The ultimate objective will be to develop an acceptable – socially and technically, proven and economically viable concept of the final disposal of the HTGR spent fuel.

The front-end research activities will focus on:

- Evaluation of the particles shape and size. 2D inspection using X-ray radiography;
- Properties of unirradiated TRISO compacts. The structural integrity of the TRISO particles. The "leach-burn-leach" test, preceded by fuel compact/pebble deconsolidation. This will be performed after compacting because specifications for particle defects are typically applied on the compact/pebble, not on the loose, as-fabricated particles. The compacting process can introduce coating damage and caused further fuel failures;
- Investigations of PyC layer anisotropy. This is a key coating layer property and is to be measured as part of fuel QC;
- Local properties in unirradiated TRISO coatings:
  - Local thermal conductivity measurement is crucial and high resolution (<1 um) mapping of thermal conductivity techniques are available. This will provide a detailed map of the thermal conductivity in each coated layer. These are very important parameters for quality control and future modeling;
Residual stresses must be measured in the coated layers, as they will impact the particle structural integrity as irradiation behavior. High resolution residual stress measurement methods are available: Raman spectroscopy, X-ray diffraction, and Focused Ion Beam based Digital Image Correlation (FIB-DIC). Undesirably high magnitude of residual stresses in the coating layers can then be detected and feedback to processing to optimize the parameters;

- Interfacial strength between coated layers. This is challenging to measure, but micro-mechanical testing could offer a solution.

The back-end research on TRISO fuel will be focused at:

- Planning irradiation experiments at MARIA reactor, constructing an irradiation sond/rig and then irradiation experiments and all PIE in the existing hot-cell lab;
- The structural integrity of TRISO particle:
  - Non-destructive measurements of coating thickness in order to document the unirradiated particles size and coating thicknesses; the same procedure can then be applied to irradiated particles to evaluate the irradiation induced dimensional changes;
  - Thermal conductivity, residual stresses are both important to measure in irradiated particles for the same reason as for unirradiated ones;
  - In situ irradiation using heavy ions in a transmission electron microscope (e.g., Ag ions) is essential for the understanding of element diffusion mechanism in buffer/IPyC/SiC. This knowledge can then be a feedback to processing for modifications in materials.
- Fission product diffusion through layers with the use of Secondary Ions Mass Spectroscopy (SIMS).

And finally, for the back-end of the HTGR nuclear fuel cycle, a set of experiments will be designed in order to prepare the strategy for the final disposal of the HTGR fuel. The basic experiments will be focused at:

- Leaching;
- Solubility in different environments and at the different temperature fields;
- Interaction between TRISO and different canister material concepts;
- Addressing the issue of the final disposal of graphite, development of technology to reduce the volume of high/medium radioactive graphite (C-14 transport);
- Experiments in the underground laboratory in cooperation with the Äspö-Hard Rock Laboratory in Sweden.

4. Conclusion

Poland has an on-going program to construct a research high-temperature reactor and then consequently deploy an industrial fleet of HTGRs. Operation of HTGR reactors requires high-quality TRISO fuel and it is of the highest priority both for licensing and for the operation of HTGR to develop a reliable supply and quality control chain of this fuel. Quality control should also be directed to investigate the aging process of fresh TRISO fuel to ensure in the long run the highest possible quality of fuel generation and storage before loading into the reactor core.

It should however be concluded that the process of establishing production and quality control lines for TRISO fuel requires time, several years to gather experience, permits, and start construction.

Failure free production of TRISO fuel is a “conditio sine qua non” for a good performance of the HTGRs aiming at minimal risk for release of radioactivity. The planned experiments presented in this paper will allow developing front-end quality control of TRISO particles through visualization and qualification of damages in TRISO. Before the irradiation experiments in the MARIA reactor, will be performed the radiation damages in TRISO fuel, will be simulated by ion irradiation. Then, by comparison, “fresh” and ion irradiated samples, it is possible to conclude the characterization of mechanical damages in individual layers, in both types of TRISO assumed.
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