

Nuclear forensics: New frontiers with Fission Track Analysis and TOF-SIMS Techniques Cumulative process.

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Introduction

Illicit trafficking of radioactive materials is known to exist from the early days of radioactive era. The nuclear forensics deals with recognizing the materials and processes of the radioactive industry. The properties of the materials can give a hint about the source of material and its original use. The most common radioactive material involved in illicit trafficking is uranium. Uranium is a common natural element which can be found everywhere. The cosmogenic uranium is well known and defined. The natural enrichment of uranium is varying within a small range around 0.72 % and is indicative to its source. The enrichment of the anthropogenic uranium can vary much depending on the purpose and use of the material. Different enrichments are known for individual nuclear power plants, research reactors and military uses. Measuring the uranium properties can indicate its enrichment, presence of other elements or impurities and can help in finding its attribution, namely its origin. To learn more about the history of found material accurate isotopic measurements are needed. The ratio between ²³⁰Th and ²³⁴U can give a good estimation of how much time passed from the last chemical cleaning of the material. This technique is called radio-chronometry or age dating. We developed new Lexan detectors with much better signal to noise ratio to improve sensitivity and reduce the false alarm, those detectors were cut by laser to avoid scratches in figure 1.

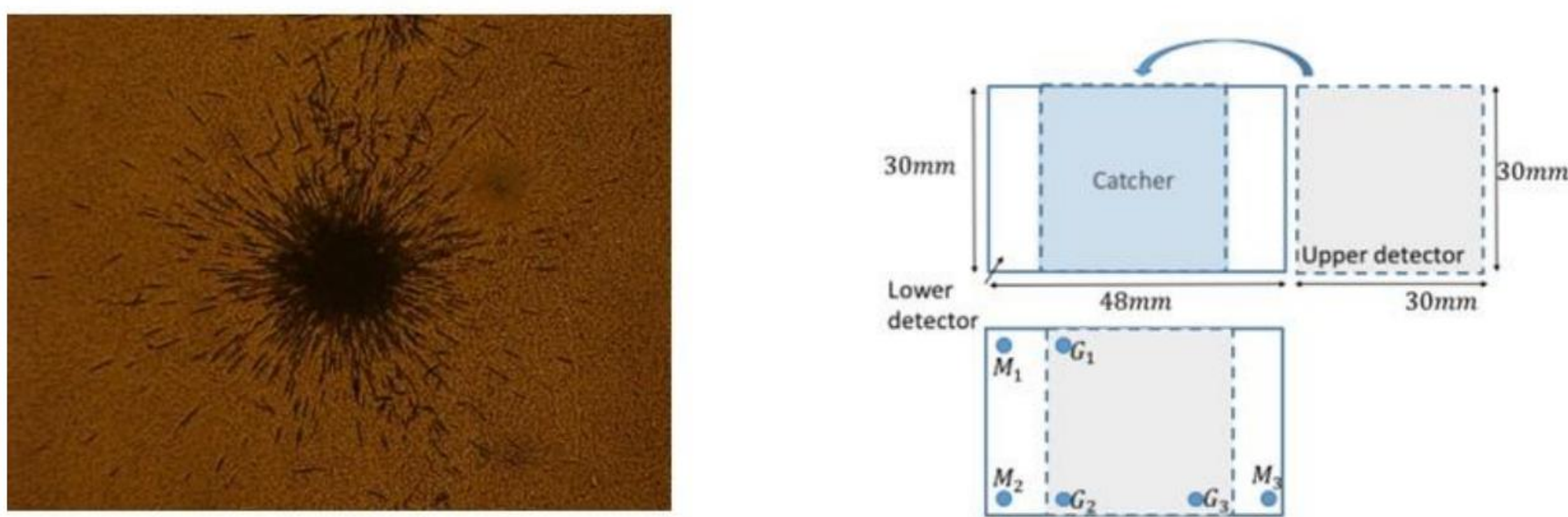


Fig. 1. FTA (Fission Track Analysis) of natural uranium mine sample.

New Automated software can recognize the fission track (FT) automatically and give the parameters of the track, like: roundness, intensity, number of tracks and color histogram. In that program we can add ROI (region of interest) or to cancel a false positive FT identification. Analytical equipment like TOF-SIMS (Time Of Flight - Secondary Ion Mass Spectrometry) and ICP-MS (Inductively Coupled Plasma - Mass Spectrometer) together with new FTA software give new frontiers to the nuclear forensic research, see figure 2.

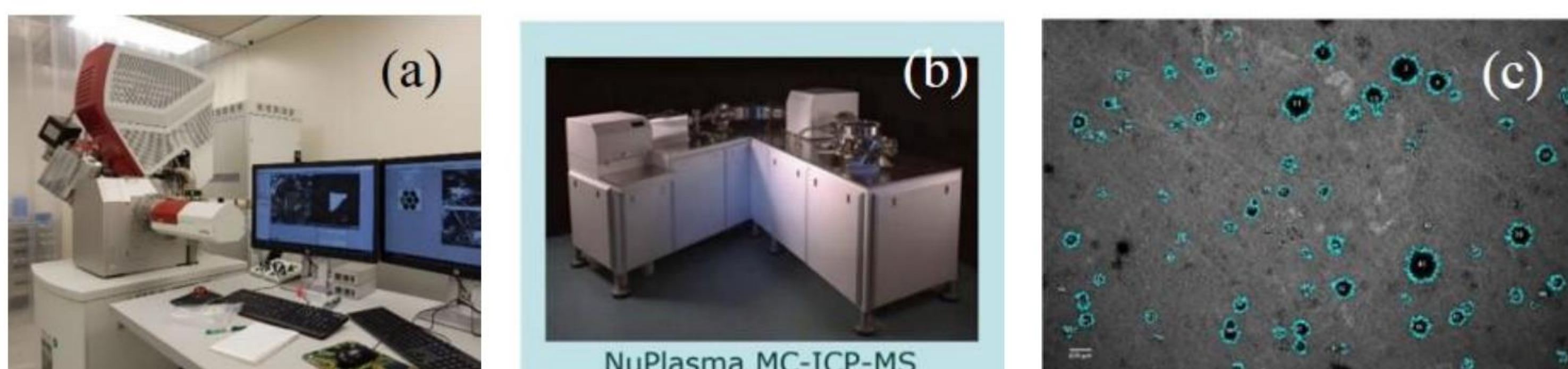


Fig. 2. TOF-SIMS (a), ICP-MS (b) and result of an automated FTA software to recognize FT (c)

A microscope equipped with TOF-SIMS gives the ability to measure quantitatively the ratio between the different isotopes and molecules. Using the scanning electron microscope, we are able to choose the desired particle (fig. 3) which can be then analyzed using the TOF-SIMS. TOF-SIMS is a technique capable to distinguish not only between elements but also different isotopes. Knowing the ratio between the isotopes is very important as it can help us to classify the material looking for its possible origin.

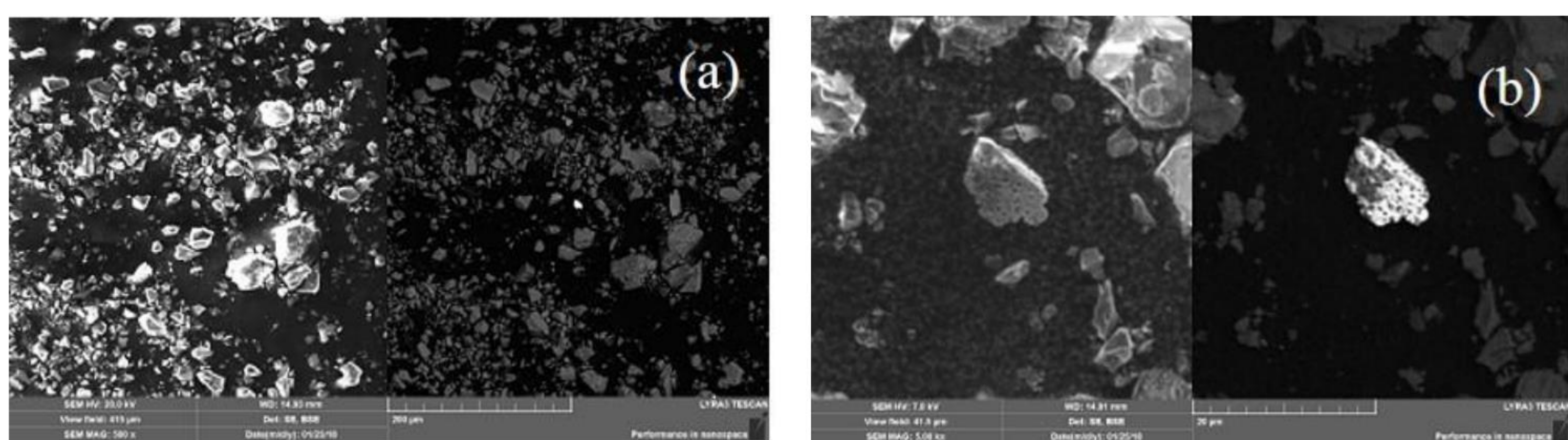


Fig. 3. The microscope image of the studied sample (a) and U particle (b) using SE detector (left) or BSE detector (right).

We used one big sample of natural uranium to measure its depth profile. By TOF-SIMS

Different nuclear reference material with a small grains size were used to simulate a forensic material collected by smear test. Each partial was too small to be measured by ICP-MS or by other chemical technique.

The new approach is to add selectively small partials to amount that can be measured with lower sensitivity and higher reliability and accuracy.

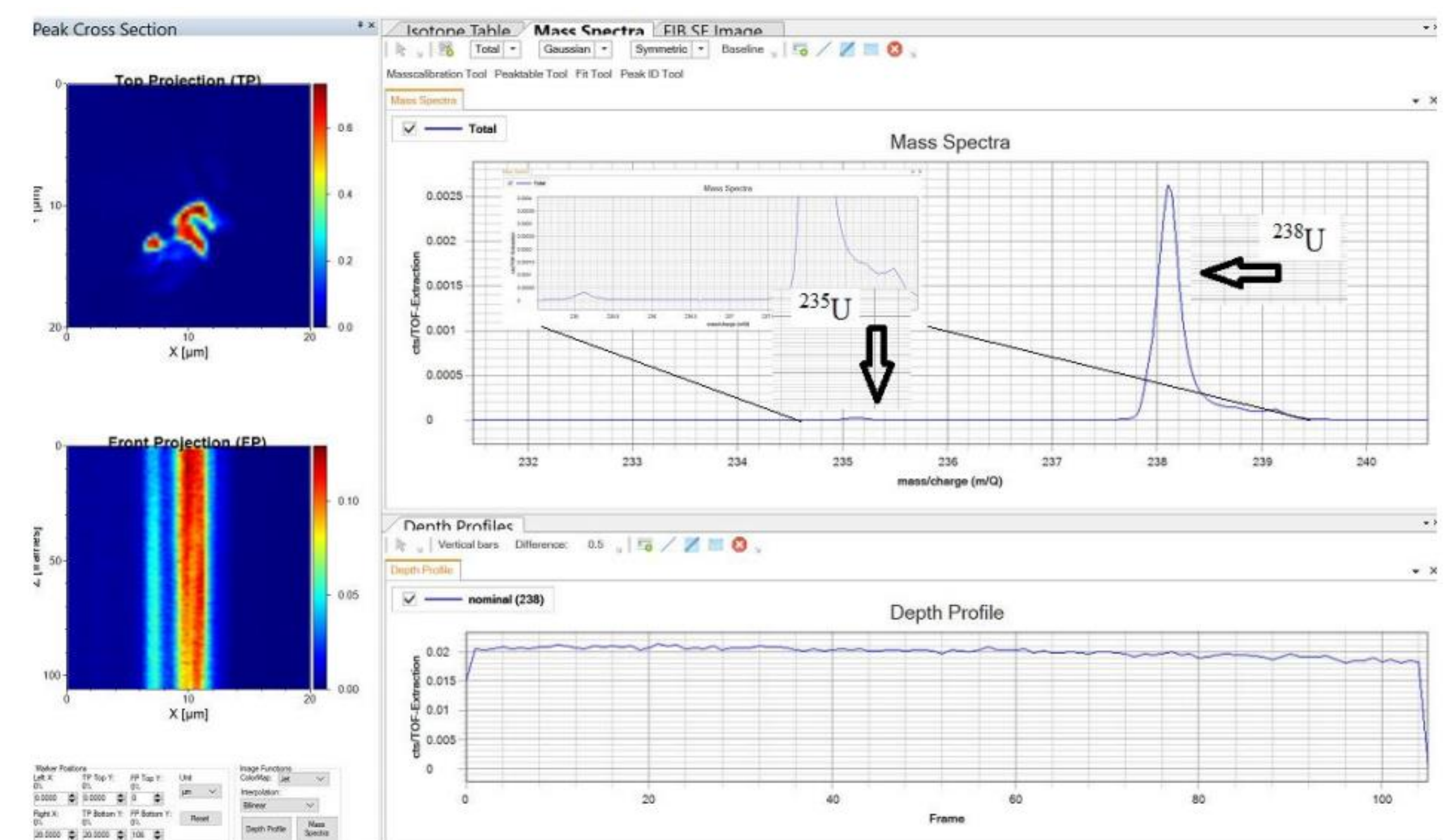


Fig. 4. TOF-SIMS analysis of uranium particle (P32), the isotopes ²³⁵U and ²³⁸U can be clearly seen.

Cumulative measurement of samples One of the advantages of using the SEM in the combined machine is the ability to select particles to be analyzed by the difference in morphology, size and atomic number (light or heavy, utilizing the BSE function). In some cases, the particles needed to be analyzed are too small and is an-usable as it is. In these cases, our new technique is to combines the TOF-SIMS data extracted from similar particles and create a multi-slice artificial particle to be analyzed. To prove this concept, we have taken six similar small different particles with the same morphology of natural Uranium enrichment. In this manner, it is possible to achieve a “selective mini-bulk” analysis.

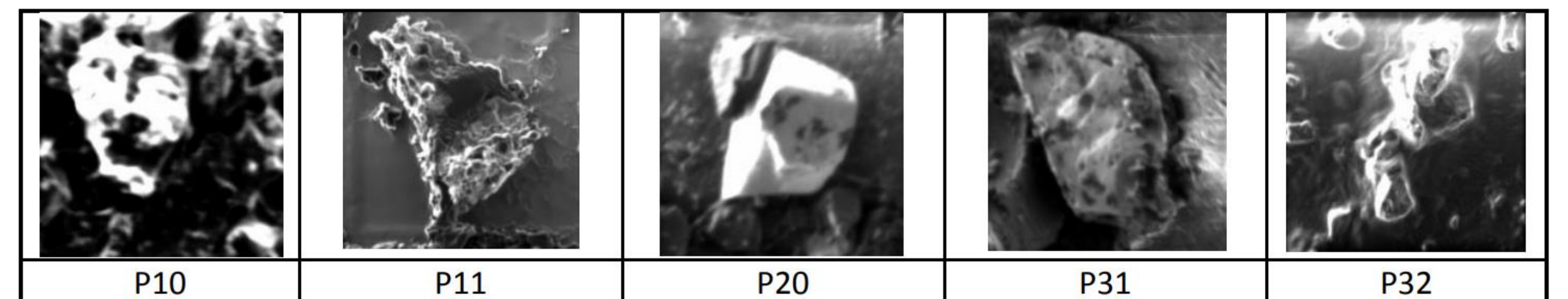


Fig. 5. The microscope images of the studied different samples chosen by their morphology

Original	P10	P11	P20	P31	P32	Average
Enrichment	0.006503	0.006476	0.008344	0.007397	0.007188	0.007190

Recombined	Slice 1	Slice 2	Slice 3	Slice 4	Slice 5	Average
Enrichment	0.007405	0.007151	0.007292	0.007232	0.007121	0.007249

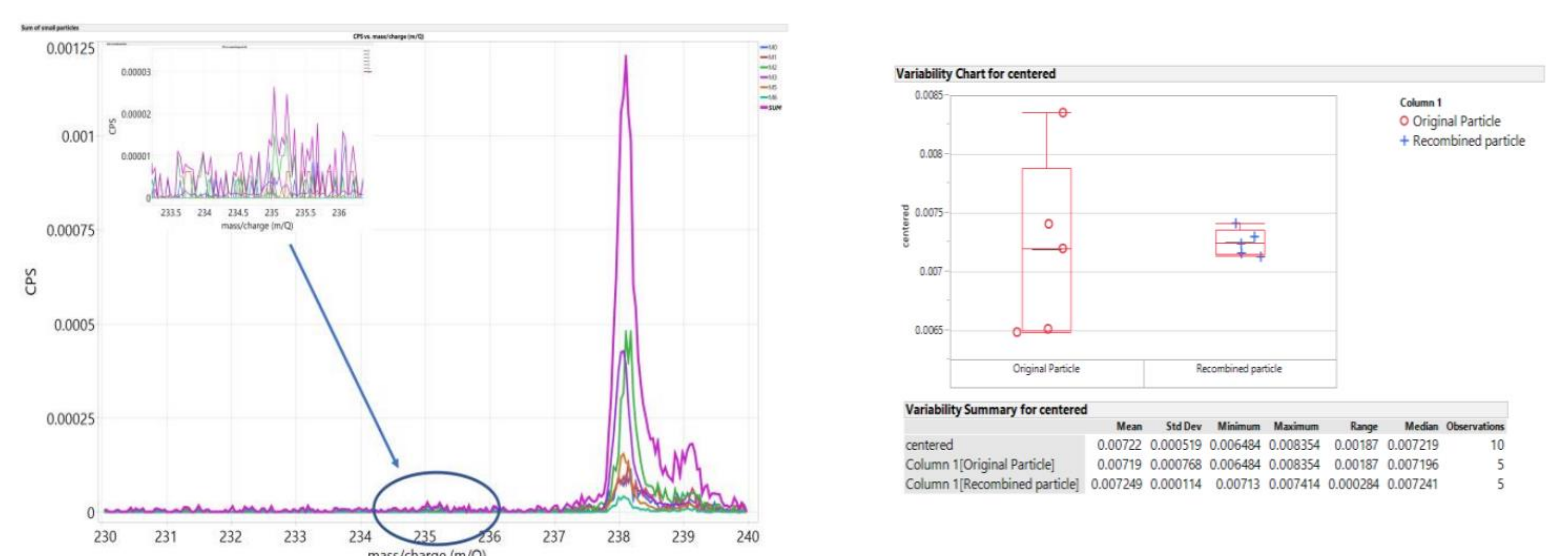


Fig. 6. TOF-SIMS analysis of cumulative uranium particles, the isotopes ²³⁵U and ²³⁸U can be clearly seen and the enrichment is calculated.

References

- [1] Itzhak Halevy, Uri Admon, Ernesto Chinea-Cano, Aryeh M. Weiss, Naida Dzigal, E. Boblil, Michal Dagan, Itzhak Orion, and Roman Radus, Progress in Nuclear Science and Technology 5:175-178, November 2018
- [2] Aryeh M. Weiss, Itzhak Halevy, Naida Dzigal, Ernesto Chinea-Cano and Uri Admon Fission Track Detection using Automated Microscopy, ASME J. of Nuclear Rad Sci. 2017; 3(3):030910-030910-7. NERS-16-1116