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Informativeness of Microparticle Analysis for Nuclear Forensics

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Investigation of individual microparticles can be useful for nuclear forensics goals in several cases:
• Determination of characteristics of nuclear material out of regulatory control, when material is not seized, but some trace amounts of material are found anywhere, including crime scene;
• Determination of the transfer rout of material, which is or was found out of regulatory control, as well as possible sites of processing, people and items, which could be involved to illicit trafficking;
• Indicating real manufacturer of the seized material, if the same materials could be produced by different manufacturers. Traces of other materials inherent to real manufacturer can indicate it in such cases;
• Determination of characteristics of nuclear materials seized out of regulatory control in the form of mixture of different materials powders.
Investigation of microparticles can provide prosecution with information about material characteristics, including age of material, as well as about mechanisms of particles formation.
Elemental composition (including impurities) of particles, isotopic composition of uranium, plutonium, other radioactive elements, content of isotopes-chronographs should be determined for material characterization. Shapes, sizes and surface structures of individual microparticles should be investigated for determination of mechanisms of particles formation and kinds of operations with nuclear materials accordingly.
One of the important characteristics of seized nuclear material is isotopic composition of uranium and/or plutonium. TIMS in combination with detection of particles by using fission track technology or SIMS are used for isotopic analysis.
In the result of sputtering of reference material particle the ratios n(235U)/n(238U) = 0,00704 ± 0,00005 and n(234U)/n(238U) = 0,0000530 ± 0,0000042 were measured. Reference ratios are n(235U)/n(238U) = 0,0070439 ± 0,0000035 and n(234U)/n(238U) = 0,000049817 ± 0,000000048. Thus, approximately 7 fg of uranium-235 in that particle was measured with relative error less than 1%, and approximately 0.05 fg of uranium-234 –was measured with relative error less than 10%. Same results were obtained for analysis of plutonium particles.
Typical particle morphologies, which can characterize the production processes, are investigated in the paper [1]. Scanning electron microscopy is used for morphology analysis. The determination of morphology details with sizes down to 0,1 µm on the surface and on the shape of microparticles is possible. Detection of particles with typical morphology allows to characterize the kind of facility, which can be concerned to the illicit trafficking of nuclear material.
Elemental composition of the particle can be determined by using energy dispersive or wavelength dispersive X-rays detectors practically together with morphology investigation. Detection limits of weight concentration for different chemical elements are (0,2 …0.5)% for energy dispersive detectors. For wavelength dispersive detectors detection limits are approximately one order smaller.
The age of nuclear and other radioactive materials can be determined by using both: bulk and particle analysis. But age determination by using bulk techniques can be correct only if one material is presented in analyzed sample and no isotope-chronograph presents in background particles. For particle analysis these restrictions are not valid. Practically one particle always characterizes only one material and does not contain background isotopes-chronographs.
Mass-spectrometer Cameca IMS-4f allows to determine the age of HEU ~ 20 y with uncertainty ~ 3,5 y in particles with sizes ~ 8 µm. First determination of the age of uranium in particles by using LG-SIMS is implemented in work [2]. More modern techniques for new LG-SIMS are now in progress.

REFERENCES

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