High Explosives (6)—Technology Data Sheet

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High Explosives (HE) Technology Name: Energy Dispersive X-ray Diffraction

Physical Principle/Methodology of Technology:

X-ray diffraction (XRD) uses the coherent scattering of X-rays from the different planes within crystal structures and may be used to identify various materials, including different explosives.

When two X-ray scattering planes are situated next to one another, X-rays scattered from these planes undergo constructive or destructive interference according to Bragg's Law. This depends on the energy of the incident X-rays, the scattering angle, and the separation distance between the planes. Typical laboratory instruments use a small diameter monochromatic X-ray beam to shine onto a finely powdered sample, which produces X-ray "rings" that may be detected at specific scattering angles around the sample according to the spacing between the atomic planes in the sample. However, this Angular Dispersive XRD method typically uses low energy X-rays, which scatter strongly but have very limited penetration ability.

This method uses a broad spectrum X-ray beam (Bremsstrahlung emission from a standard X-ray tube) at higher energies with an X-ray spectrometer fixed at a specific scattering angle. In this case, the energies of the X-rays that meet the Bragg condition for diffraction will produce peaks in the detected energy spectra, which in turn correspond to the different plane spacing within the material. The detection angles for diffracted X-rays are kept low to observe diffraction from higher energy X-rays that have better penetration characteristics.

Because each different chemical material has different spacing between atoms, it is possible to produce a library of the diffraction patterns produced by different materials and chemicals, which can be used for identification of unknown samples.

There has been some work undertaken by industry to use this technique to provide information about liquids as well as crystalline solids.

A portable energy dispersive X-ray diffraction (EDXRD) system that aims to provide through barrier material identification is in development, however it is currently at a low TRL and will require significant development before it could be used operationally, such as producing a suitable material library for identification of these materials.

Potential Monitoring Use Cases (pre-dismantlement, dismantlement, post-dismantlement, storage stage):

Verification of explosives that are present/absent.

Pre-dismantlement: Unlikely due to penetration of dense materials; measurement only possible if a scanning angle can be achieved, which has limited thickness and density of barrier materials, and does not pass through dense fissile material.

Dismantlement: As above.

Post-dismantlement: As above .

Storage stage: As above.

For detection technologies, what does the method determine/measure?

Presence/absence of HE.

Identifies the type of explosives present. Most explosive materials produce a strong diffraction signal, each produces its own diffraction "fingerprint" that can be used for its exact identification.

Materials library for system does not currently exist and would require extensive work to produce.

Physical Description of Technology (e.g., approximate size, weight):

Planned detection system will consist of an X-ray tube connected to a fixed angle collimator with detector at a set distance by a c-arm arrangement, allowing them to be positioned either side of an item whilst maintaining alignment. System weight (mostly X-ray tube) estimated at about 70 kg. Current laboratory setup has X-ray source and detector setup mounted on an optical bench.

Time Constraints (e.g., measurement times including distance from object, time to install the equipment):

Final system should take a few minutes to deploy and about 5 minutes to produce a measurement.

Will this method work in the presence of shielding? If so, what is the maximum amount of shielding that will still allow the method to work?

This method will penetrate some shielding before diffracted X-rays are attenuated. Caffeine diffraction signals have been observed through an aluminum box with 2 mm thick walls. Higher density materials are very difficult to penetrate.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

A finished system should be easy to set up and operate.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

Electrical power, radiological shielding/exclusion zone.

Technology Limitations (e.g., detection limits for HE, operational temperature range, differences in technology detector materials):

Requires transmission of X-rays through the object; access to opposite sides required. There is a physical limit to the thickness of material that can be measured because diffracted X-rays are attenuated within the material, and high-density materials are difficult to penetrate. Current lab prototype can penetrate 4 mm Al, but cannot penetrate 10 mm ^{238}U radiation.

Information Collected by the Technology (used to help determine if an information barrier is required for use):

Presence/absence of HE. Identifies the explosives.

Safety, Security, Deployment Concerns: System uses hazardous ionizing radiation from an X-ray generator. Site radiography rules must be in force when used.
Technology Development Stage (Technology Readiness Level, TRL): Commercial EDXRD systems exist for baggage screening but the portable system in development is currently TRL 3/4.
Where/How the Technology Is Currently Used (e.g., international safeguards, border protection): EDXRD has been used in a limited number of baggage screening machines.
Examples of Equipment: Morpho XDi baggage scanner