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Secondary electron equilibrium revisited: when doses are given by photons

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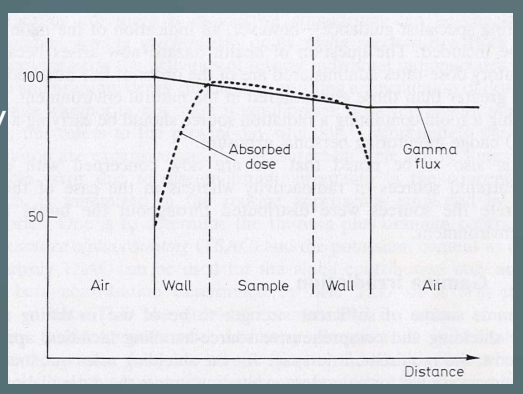
Why are X and γ rays ionizing radiations?

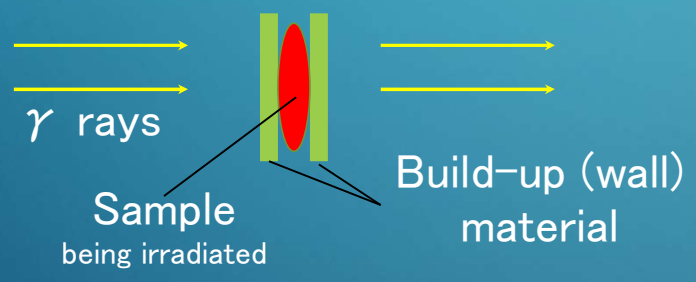
It is well known that X and γ rays are ionizing radiations that create trapped charges in minerals used for dating. Do you know why those photons with no electric charges have the effect of ionization in materials? The answer is that they induce secondary electrons through various processes, such as the photo electric effect, Compton scattering, and pair (electron positron) productions.

Build-up materials are necessary

As the radiation effect (creating trapped charges) is caused by these secondary electrons, "build-up" materials (wall) are necessary in front and at the back of the samples being irradiated when artificial irradiation is made.



The part of the material close to the surface will not receive secondary electrons of equilibrated amount as shown in this figure (Aitken, 1998, p. 48). The thickness of the wall (build-up) material should be equal to or larger than the range of the secondary electrons, which is typically about 2 mm.

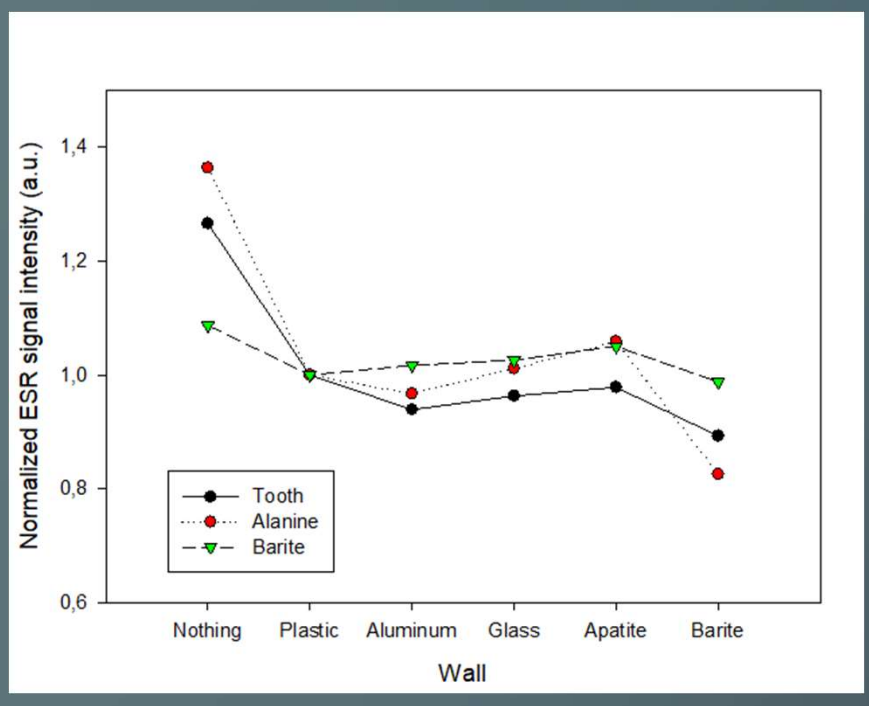


The motivation and the purpose of the present study

However, the above figure should not be really right as the air will also create secondary electrons, i.e., the air may work as the build-up material. It would also be an important issue what build-up material should be used when irradiated. Theoretically, the build-up material should be the same as the sample being irradiated, but it may not be the cases of actual irradiation. Therefore, we tested the variation depending on the build-up materials.

Mass energy absorption coefficient relative to water					
Air	plastic	Al	Qz	apatite	barite
0.90	0.98	0.87	0.90	0.93	0.88

Results



normalized by the intensity with plastic plates

Experimental set up

Samples
- Human Tooth enamel, 1.9 Gy
- Alanine, 1.9 Gy
- Barite ($BaSO_4$), 1.07 kGy

Build-up materials
- (1) Nothing
- (2) Plastic, 3.8 mm
- (3) Aluminum, 2.0 mm
- (4) Glass, 2.5 mm
- (5) Apatite, 1.6 mm
- (6) Barite, 2.3 mm

Irradiation

^{60}Co source at Takasaki Advanced Radiation Reaserch Institute of QST (National Institutes for Quantum Science and Technology).

Discussions

With no build-up material, the observed signal intensities were much higher than those with build-up material, which is contrary to Aitken (1985, 1998). This is probably due to secondary electrons produced in air, in the concrete walls of the irradiation facility, and in the stainless steel cover of the ^{60}Co source, where the range of electrons are several meters in air.

The actual radiation effect (production of trapped charges) should be proportional to mass energy absorption coefficients shown in the left bottom. As shown in the experimental results above, the tendency, –higher with plastic, getting lower to higher with Al to apatite and lower in barite–, is qualitatively roughly consistent with the mass energy absorption coefficients. The present work shows the importance to place appropriate build-up materials at the time of gamma ray irradiation. Without the material, given doses can be much higher, being contrary to textbook.