Radiation Damage in Alumina irradiated with heavy Ions of high Fluences*

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Scintillating screens are used at accelerator facilities for ion beam diagnostics with very high ion fluences. However, during irradiation of the material, formation of color centers occurs. This results in a degradation of light yield, which is one of the main problems using the screens as an appropriate tool for imaging the beam [1]. Due to its radiation hardness, alumina is an interesting material for scintillation applications [2]. Another advantage of using Al_2O_3 is that the understanding of its luminescence behavior is at an advanced stage [3].
High purity (99.9 %) alumina samples were irradiated with different ion species and different fluences (see table 1). The given value for the dose is integrated over the ion range, although the energy dissipation is a function of ion velocity [1, 4].

Table 1: Parameters for irradiation of the alumina samples. The range values are calculated with SRIM-2013 code.

Ion species	Energy [MeV]	Range [μm]	Dose [MGy]	Fluence [ions/cm^2]
^{12}C	136.8	169	0.09	$2.8{\cdot}10^{11}$
^{12}C	136.8	169	1.36	$4.1{\cdot}10^{12}$
^{50}Ti	570	78.6	0.30	$1.0{\cdot}10^{11}$
^{50}Ti	570	78.6	3.87	$1.3{\cdot}10^{12}$
^{197}Au	1162.3	37.3	0.64	$5.0{\cdot}10^{10}$
^{197}Au	1162.3	37.3	1.28	$1.0{\cdot}10^{11}$
^{197}Au	1162.3	37.3	6.39	$5.0{\cdot}10^{11}$
^{197}Au	1162.3	37.3	12.78	$1.0{\cdot}10^{12}$

After irradiation, absorption measurements were performed. F- and F_2-color centers are observed due to strong absorption bands in the range from 200 nm to 450 nm (figure 1).

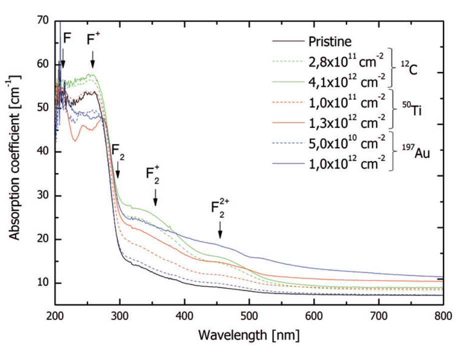

Figure 1: Absorption spectra of alumina samples irradiated with different ion species of given fluences.

To calculate the color center concentration the Smakula-Dexter formula was used (equation 1, [5]).

$$N_{[1/cm^2]} = 6.55 \cdot 10^{15} \cdot \frac{1}{f} \cdot FWHM_{[eV]} \cdot A, \qquad (1)$$

where A is the absorbance at peak maximum, *FWHM* is the full width at half maximum of the absorption peak and f is the oscillator strength ($f_F = 1.3$ respective $f_{F+} = 0.6$). The volume concentration of F-centers as a function of the applied dose is shown in figure 2. The formation of color centers centers in alumina depends mainly on the ion species and on the applied dose. The fitting of data obeys an exponential law:

$$N_F = N_0\left(1 - exp\left(\sigma_D \cdot D\right)\right) \qquad (2)$$

For low energy doses, color center formation complies with exponential growth. For higher doses of around 6 MGy, saturation in the concentration of color centers can be determined.
Further measurements will are planned to investigate color center formation for high energy ion doses.

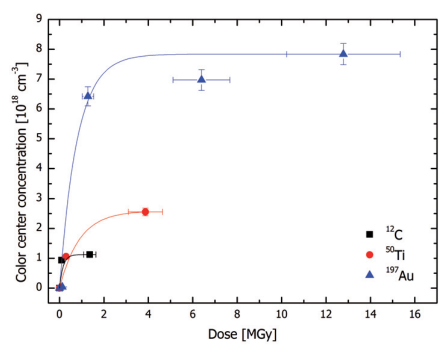

Figure 2: Volume concentration of color centers as a function of the applied dose. Solid line: fit with exponential growth function (2).

References

[1] E. Gütlich, P. Forck, B. Walasek-Höhne and W. Ensinger, IEEE T. Nucl. Sci 59 (2012) pp 2354-2359.

[2] N. Khalfaoui, J.P. Stoquert, F. Haas, C. Trautmann, A. Meftah and M. Toulemonde, Nucl. Instrum. Methods Phys. Res., Sect. B 146 (2012), pp 247-253.

[3] B.D. Evans, J. Nucl. Mater. 219 (1995), pp 202-223.

[4] P.A. Rodnyi, *Physical Progress in inorganic scintillators*, (CRC Press, New York, 1997)

[5] D. Curie, *Luminescence in crystals*, (Methuen&Co Ltd, London, 1963).

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