Luminescence degradation behavior of alumina irradiated with heavy ions of high fluences*

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Polycrystalline α-alumina samples (purity: 99.8 %) were irradiated with different fluences at various energies. To compare the degradation behavior of the luminescence, similar ion species were used (^{58}Ni @ 300 MeV/u, at slow and fast extraction mode, measured at GSI and ^{63}Cu @ 0.5 MeV/u, measured at Helmholtz-Zentrum Dresden-Rossendorf). Ion-beam induced luminescence (IBIL) was monitored at wavelengths from 320 to 800 nm.

Scintillation Screens

Scintillating screens are used at accelerator facilities for ion beam diagnostics with very high ion fluxes. However, during irradiation of the material, formation of color centers with one or two trapped electrons occurs [1]. The increasing radiation damage leads to massive degradation of light yield, which is one of the main problems using the screens as an appropriate tool for beam imaging [2]. Due to its radiation hardness, alumina is an interesting material for scintillation applications [3].
Models of scintillator degradation behavior have been developed for many years, whereas many of them are related to the basic approach of Birks and Black [4]. The parameter of technical interest in beam diagnostics is the so called critical half-life fluence Φ_c. Therefore, a modified model according to Miersch et al. [5] is used to determine the dose dependent luminescence behavior and the radiation hardness of the alumina screens.

Results and Discussion

In Figure 1 the relative scintillation yield of alumina as a function of the applied particle fluence is shown. IBIL data are normalized by the initial scintillation yield S_0. The luminescence S decreases for increasing fluence Φ due to enhanced defect creation. To explain the dynamic behavior of the luminescence, the empirical model according to Miersch et al. was used (Eq. 1).

$$\frac{S}{S_0} = \frac{1}{1 + (\frac{\Phi}{\Phi_c})^c} \quad (1)$$

Within Eq. 1 the factor Φ_c describes the critical half-life fluence, and the exponential value c describes the slope of the scintillation yield's decrease. The model has been used to fit the data in Figure 1, results are summarized in Tab. 1. Half-life fluence Φ_c increases for higher energies, indicating an enhanced radiation hardness. According to SRIM simulations, less defects are created at low electronic stopping powers dE/dx_e, suggesting that the effective quenching of luminescence centers is reduced for higher energies. The exponential value c is also reduced for high energy irradiation due to the less decreasing slope.
The results show, that high energy operation enables a prolonged use of the scintillation screens due to the reduced creation of radiation defects.

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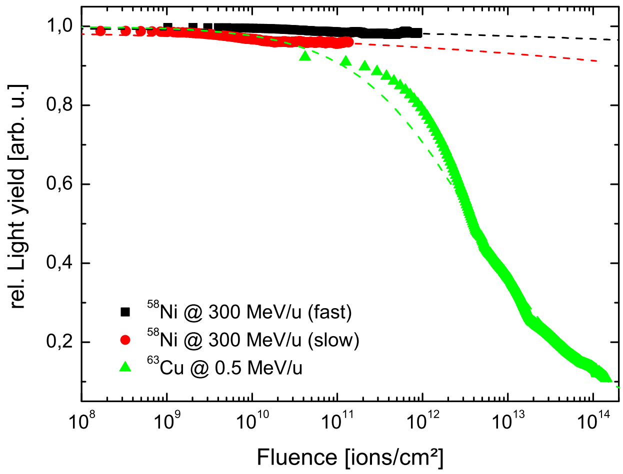

Figure 1: Relative scintillation yield of α-Al_2O_3 versus ion fluence for different ion species at various energies.

Table 1: Derived critical half-life fluences Φ_c and exponential values of c for the alumina samples. The electronic energy loss values are calculated with SRIM-2010 code.

Ion species	Energy [MeV/u]	dE/dx$_e$ [keV/nm]	Φ_c [ions/cm^2]	c [arb. u.]
^{58}Ni (slow)	300	0.9	$1.18 \cdot 10^{26}$	0.13
^{58}Ni (fast)	300	0.9	$9.24 \cdot 10^{22}$	0.11
^{63}Cu	0.5	11.6	$4.17 \cdot 10^{12}$	0.61

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