2 - 12 Dependence of X-ray Emission Cross Section on Energy Loss Straggling

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The Bethe-Bloch method describes the energy loss of ions penetrating solid matter reasonably well. The majority of the interaction processes is with loosely band outer electrons. These processes lead to a Gaussian distribution of the energy loss straggling. Inner shell processes are comparatively random and transfer more energy in a single collision. This leads to an asymmetric energy loss distribution and was observed by L. D. Landau in 1944 which is shown in Fig. 1. Since the X-ray emission cross section scales with about υ_p^4 where υ_p is near the Bohr velocity. It is very important to take into account the correct energy distribution around the average energy given by the Bethe-Bloch energy loss.

N. Bohr firstly obtained the energy loss straggling formula using classical method. Then J. Lindhard and M. Scharff expanded the Bohr model for the low and intermediate energy range as shown in Eq. 1.

$$\Omega_{e,L}^2=\begin{cases}\Omega_e^2\,\dfrac{1}{2}L(x), & x\leqslant 3\\ \Omega_e^2 & x\geqslant 3\end{cases} \tag{1}$$

$$x=\upsilon^2/Z_2\upsilon_0^2$$

where x is the reducedenergy, $L(x)$ is the stopping number[1], Ω_e^2 is the energy loss straggling obtained by N. Bohr.

We compared the results of X-ray cross section based on the ECPSSR model with the projectileenergy derived from the Bethe-Bloch formula to the situation where an energy distribution due to straggling is taken into account. We found that if the initial projectile kinetic energy is 250 keV, this corresponds to 150 keV in the model with asymmetric energy distribution. The difference of X-ray cross section is 10%. For the 100 keV case the difference of those two methods is even 20%. Over the whole stopping range this amounts to a difference in the total cross section of 5.3%. More specific data are shown in Table 1.

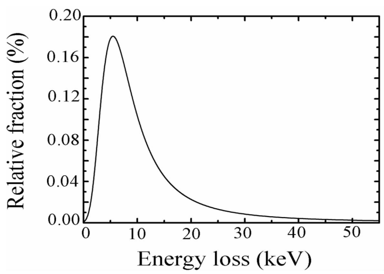

Fig. 1 Energy loss distribution of proton penetrating Al solid target.

Table 1 Comparison of the cross sections calculated by two methods

	E_I	300	250	200
E_V	CS_M		CS_{ELS}	
175	15.3	13.5	14.2	14.7
150	9.07	7.76	8.08	8.44
100	2.05	1.60	1.68	1.77
Difference		6.3%	5.3%	4.6%

E_I the initial energy and E_V the evolution of the kinetic energy. CS_M the cross section through mean energy and CS_{ELS} is taking the energy loss straggling into consideration. Difference the total cross section discrepancy by those two methods.

We conclude that it is necessary to take the energy loss straggling into account.

References

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