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Review

Relationship between ion energy and lateral straggling in solids, gases, liquid and air

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The aim of the present work is to study the relation between ion energy (10KeV to 900KeV) and the straggling lateral (N, O, H in N), (Cu, F, Ag in Ag) (Si, Ge, Bi in Si), (N, Ag, Si in water), (N, Ag, Si In Air). We studied the stopping power and the energy-loss straggling as a function of the projectile energy, the variance of energy loss which is called (straggling). Collisional straggling expected to be the only contribution for high energy bare ions and that can be calculated by several theories. The interaction incident ions with different targets additional information atomic-collision phenomena such as loss and cubature electrons, explain the structure of material and the relation between loss electrons and binding energy etc. also due to several applications the stopping power and the energy-loss straggling of swift projectiles in matter is important for many practical applications in different research areas such as microelectronics, surface analysis, nuclear physics, space exploration, protection against radiation, and radio-therapeutic medicine.

Key words: Stopping power, straggling, Ion energy.

INTRODUCTION

The stopping power can be divided into nuclear stopping and electronic stopping terms. The nuclear stopping governs the energy losses caused by elastic collisions between the ion and the nuclei of atoms in the target. The electronic stopping term governs the energy losses caused by the electronic interaction (Peltola, 2003).

The characterization of energy dissipation of heavy projectiles, the average energy loss is a key quantity, both experimentally and theoretically (Nagy et al., 2008). The energy losses and energy loss straggling of fast charged particle interacting with various materials are investigated both experimentally and theoretically in many scientific center (Makarov and Matveev, 2012).

When swift charged particles penetrate matter, they lose energy almost entirely through inelastic collisions with the electrons of the stopping material. This is not a continuous process, but is made up of small but finite losses in a large number of collisions. The statistical nature of these collisions gives rise to a dispersion in the ion energy-loss spectrum, usually known as energy-loss straggling (Montanari and Miraglia, 2007).

THEORY

Several characteristics of the particle-deceleration process are important in understanding their behavior. The first one is the stopping power of the medium, a quantity that measures the rate of energy loss per unit distance along the path: (Ligia and Gheorgh, 2009).

$S(E) = -dE/dx$..1

Electronic stopping power considers slowing down of the ion due to the inelastic collisions with electrons in the medium. The nuclear stopping power takes into account nuclear elastic and inelastic scattering processes. The electronic stopping power is by far larger than the nuclear stopping power, till the last part of the trajectory where the nuclear becomes dominant.

The interaction between an incident ion and an atomic electron can be written by scattering of a Dirac particle

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(Saad and Boualem, 2002).

$$d\delta = \frac{e^2 p^2 v^2(q)}{4\pi^2 \hbar^4 c^2 \beta^2}\left(1-\beta^2 \sin^2\frac{\theta}{2}\right)d\omega \quad \ldots\ldots\ldots\ldots\ldots 2$$

Where;
e is the electron charge,
$v(q)$ is the Fourier transform

$$p = m_e v/\left(1-\beta^2\right)^{1/2},$$
$$d\omega = 2\pi \sin\theta d\theta$$
$$c = 3\times 10^8$$

The energy of incident ion given as:

$$T_e = E\left\{1-(M-m_e)^2\left[(M+m_e)^2+2m_e E/c^2\right]^{-1}\right\} \ldots 3$$

Where M is the incident ion mass, m_e is the electron mass, rewriting $d\delta$ in terms (Nagy et al., 2008) of T_{max} and inserting in the usual definitions (Bevelacqua and Bevelacqua, 2005) of the target stopping power and the incident ion energy straggling variance per unit.

$$S(E) = NZ_2\int T_e d\delta \quad , \quad d\Omega^2 = NZ_2\int T_e^2 d\delta \quad \ldots\ldots\ldots 4$$

$$S(E) = \frac{m_e e^2}{2\pi\hbar^4 c^2}\frac{NZ_2}{T_e^{max}}\int_w^{T_{MAX}}\left[\left(2m_e c^2+T_e^{max}\right)T_e - T_e^2\right]\times v^2(T_e)dT_e \ldots\ldots\ldots 5$$

$$d\Omega^2 = \frac{m_e e^2}{2\pi\hbar^4 c^2}\frac{NZ_2}{T_e^{max}}\int_w^{T_{MAX}}\left[\left(2m_e c^2+T_e^{max}\right)T_e^2 - T_e^3\right]\times v^2(T_e)dT_e \ldots\ldots 6$$

Where the lower integration boundary w is the smallest energy required for ionization (independent both from the nature and energy E of the incident ion (Alfred et al., 1990) and (N, Z2) are the target atomic density and atomic number. Using a Coulomb potential $V(r) = z_1 e/r$ (Ligia and Gheorgh, 2009) leads to the relativistic Bohr formula for the collisional straggling;

$$\Omega^2 = 4\pi Z_1^2 e^4 NZ_2 \Delta x\left(1-\beta^2/2\right)\left(1-\beta^2\right)^{-1} \ldots\ldots\ldots\ldots\ldots 7$$

Ion energy

Ions are defined as atoms or molecules that have lost or gained electrons. (Electrons are the only easily available charge carriers.) When an atom or molecule has an equal number of electrons and protons it is electrically balanced, or neutral. If an electron is lost, the atom or molecule becomes positively charged and is a positive ion. Gaining an electron makes it a negative ion (Glen, 1989).

The charged particles in their passage through matter lose energy dominantly as a consequence of the excitation and ionization of the atoms and molecules of the medium. Energy-loss mechanisms as ionization and excitation could break chemical bonds and generate reactive species that cause further chemical reactions. In the second order of intensity occur elastic and inelastic interactions with the atomic nuclei of the stopping medium. The atomic and molecular interactions occur through the Coulomb force between the positive charge of the beam particles and the negative charge of the electrons from the stopping medium (Makarov and Matveev, 2012).

Air is a mixture of gases, including nitrogen, oxygen, carbon dioxide, water vapor, and other trace gases, any one or more of which may be ionized. Sometimes a diatomic gas molecule, such as nitrogen or oxygen, will gain or lose the electron. Sometimes it will be a more complex gas such as carbon dioxide. In any case, when molecules of one or more of the gases in air gain or lose electrons, the result is conventionally called air ions (Santiago et al., 2007).

Stopping particle in material

The energy loss and the range of ions in matter are of interest in many disciplines of science such as radiation physics, radiation damage, material analysis by ion beams, In transport theory, the range distribution of ions in matter is commonly calculated by using a transport equation which determines the motion of ions during their slowing down to zero energy. The interac- tion between the ions and the target atoms can be separated into two parts where the part involves binary elastic collisions between an ion and a target atom and the second part is attributed to inelastic collisions between the ion and the electronic part of the target system (Arnold, 2006).

The energy-loss straggling, defined as the variance in the energy-loss distribution per unit path length The contribution to the energy-loss straggling due to the target K-, L-, and M-shells becomes appreciable for projectile energies (Johns and Cunningham, 1983).

Straggling depends on target material, beam energy and incident particle (Harris and Anicolet, 1975). The statistical nature of ionization energy loss, large fluctuations can occur in the amount of energy deposited by a particle traversing an absorber element (Saad and Boualem, 2002). The straggling is independent of the components to be summed in quadrature:

(i) the collisional straggling expected to be the only contribution for high energy bare ions and that can be

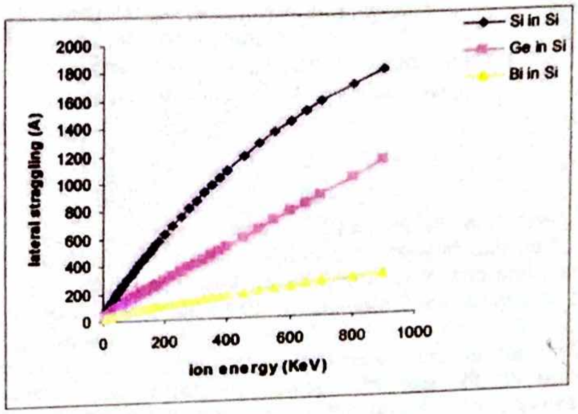

Figure 1. Lateral straggling as a function of the ion energy, incedent ion semi. (Si,Ge,Bi in Si).

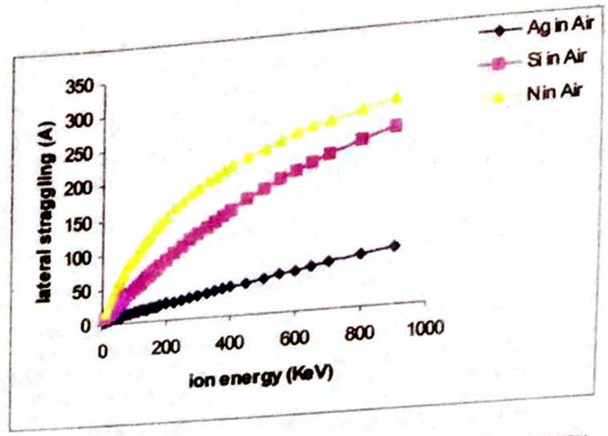

Figure 4. Lateral straggling as a function of the ion energy, incedent ion (Ag,Si,N in Air).

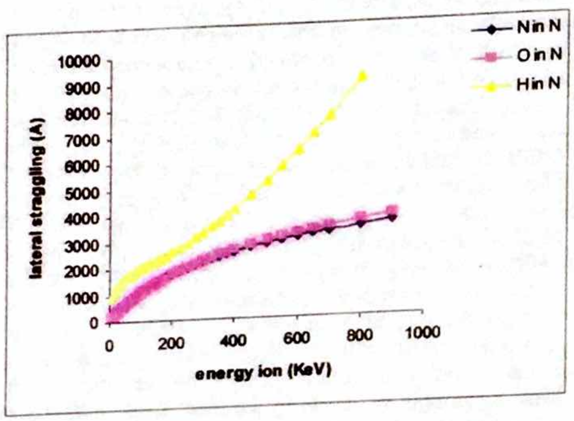

Figure 2. Lateral straggling as a function of the ion energy, incedent ion gas. (N,O,H in N).

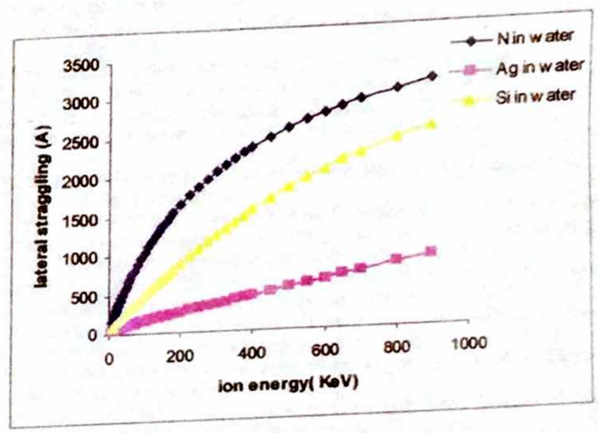

Figure 5. Lateral Straggling as a function of the ion energy, incedent ion (N,Ag,Si in water).

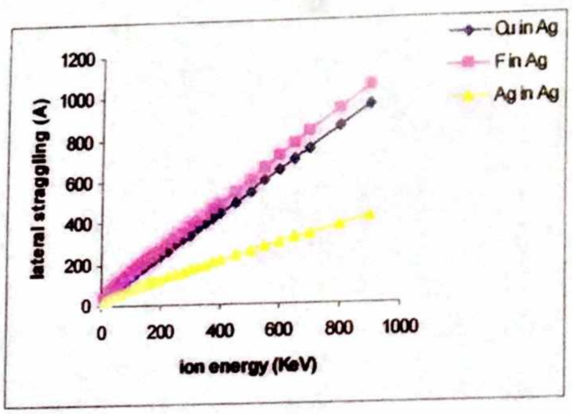

Figure 3. Lateral straggling as a function of the ion energy, incedent ion. (Cu,F,Ag in Ag).

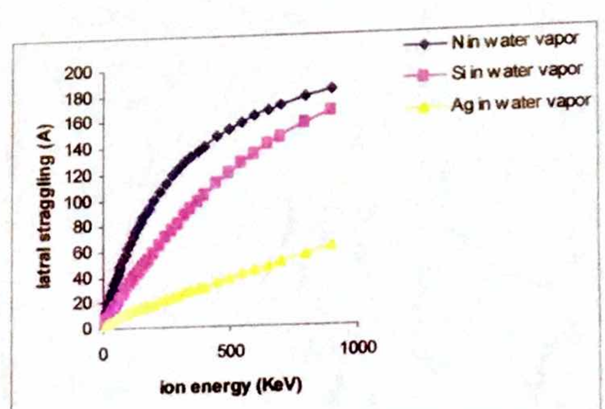

Figure 6. Lateral Straggling as a function of the ion energy,incedent ion .(N,Ag,Si in water vapor).

calculated by several theories assuming a constant charge of the projectile,
(ii) the charge-exchange straggling prominent around the stopping power function Ivanchenko, 1999).

DISCUSSION

The ion energy and the straggling of any energetic charged particles travelled in any medium can be found by using the software called SRIM (Stopping and Range of Ions in Matter), used to calculate the energy ions and lateral straggling.

There are many factors that determine the ion motion inside the target and cause the loss of its energy gradually until it stops within the article. The process of energy loss depends on the type of target material (solid, liquid, gas) in terms of atomic number and the angle of the fall of the ion. As shown in Figures (1,2,3), If the target is a solid material (metal), the number of collisions will be large, because the inner distances between the atoms of target are small and the atomic number is more than semiconductor and gases, therefore in solid the ion lose it energy gradually until it stops inside the target after a short distance. In the semiconductor and gases the collisions be less and the ion move largest distance within the article and ion (straggling) is largest. But if the fall of the ion is vertical, it loses all its energy at once than if they fall at any angle.

Figure 4 shows the movement of ions (Ag, Si. N) in the air, the straggling for ion N in air is 300A, Si is 250A and Ag is 75A that is because the number of atom in Ag more than Si and N therefore the number collision Ag with air larger and the straggling is less from Si and N, there are many factors that effect to stop this ion in air such absorption and scattering. Also in figures 5 and 6, the falling of ions (Si, N, Ag) in water (liquid) and water vapor was determined and the difference in straggling found, because of the different densities between water and steam, we find the straggling of the ions in the vapor reached to be 700A while in the water 350A as the ions suffer collisions in H_2O molecule, where the existence of bonds help to stop the ions, and the density help to stop the ions in water.

REFERENCES

Peltola J (2003). Stopping power for ions and clusters in crystalline solids. University of Helsinki Report Series in Physics.

Nagy I, Vincent R, Juaristi I, Echenique P, (2008). Energy loss straggling of swift heavy ions in an electron gas, Physical Rev., A78,012902.

Makarov D, Matveev V, (2012). Energy loss straggling of fast charged particales, ISSN,0021-3640, 95(3): 115-121.

Montanari C, Miraglia J (2007). Calculaertion of energy-loss straggling of C,al,Si and Cu for fast H,He and Li ions,physical Rev.A75,022903.

Ligia S, Gheorgh C (2009). Heavy ions straggling in Biologlcal matter,U.P.B.Sci.Bull.,series A, 71: 3.

Saad O, Boualem B, (2002). Energy loss straggling of swift heavy ions below 100MeV, Nuclear Instrument and Methods in physics research B193, Pp: 36-42.

Bevelacqua J, Bevelacqua R, (2005), Systematics of Heavy Ion Radiotherapy, Radiation Protection Management, 22: 6.

Alfred B, Michael O, Peter B, Johannes G, Michael A, (1990). Charge exchange of low-energy ions in thin carbon foils, J. Appl. Phys., 68: 2547.

Glen F (1989). Radiation Detection and Measurement, second ed., J. Wiley & Sons, New York.

Santiago H, Isabel A, Cristian D, Juan C, Rafael G (2007). Target inner-shells contributions to the stopping power and straggling for H and He ions in gold, J.Phys.,Condens matter 19, 466205 (8pp).

Arnold S (2006). Basics of Air ionization for high technology manufacturing Application compliance Engineering.

Johns H, Cunningham J (1983). The Physics of Radiology, Fourth Edition, C. C. Thomas Publisher, Springfield, IL.

Harris J, Anicolet M (1975). Energy straggling of He ions below 2MeV in Al,Ni and Au,Physical Rev.b, 11: 3.

Ivanchenko V (1999). GEANT4 Simulation of Energy Losses of Slow Hadrons, CERN-99-121, INFN/AE-99/20, (September).