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Calculation of Stopping Power for Protons, Carbon and Oxygen Ions in C_2H_4O, C_3H_3N Polymers

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ABSTRACT:

In this research , the electronic stopping power was calculated using Bethe and Bragg rule equations for the protons , carbon and oxygen ions in the polymers (C_3H_3N ,C_2H_4O) in energy range of (0.01-1000) MeV. The equations were programmed using MATLAB 2016 , the calculations were compared with the experimental data of the SRIM2013program and PSTAR code. This comparison showed a good agreement with experimental data . As shown results that stopping power calculated according to Bethe equation in this polymers (C_3H_3N ,C_2H_4O) get the case a cut off in energies (0.01-8) MeV for carbon and oxygen ions.

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حساب قدرة الايقاف للبروتونات وايونات الكاربون والاوكسجين في البوليمرات (C_3H_3N ,C_2H_4O)

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الكلمات المفتاحية:

قدرة الايقاف
SRIM2013
PSTAR
بيث
قاعدة براغ
خسارة الطاقة

الــخُــلاصــة:

في هذا البحث تم حساب قدرة الإيقاف الالكترونية باستخدام معادلات بيث و قاعدة براغ للبروتونات وايونات الكاربون و الاوكسجين في البوليمرات (C_3H_3N , C_2H_4O) في مدى طاقة (0.01-1000) MeV . تم برمجة المعادلات باستخدام MATLAB 2016 ، تمت مقارنة الحسابات مع البيانات التجريبية لبرنامج SRIM2013 و PSTAR code . أظهرت هذه المقارنة توافقاً جيداً مع البيانات التجريبية . كما أظهرت النتائج أن قدرة الايقاف المحسوبة طبقاً لمعادلة بيث في البوليمرات (C_3H_3N ,C_2H_4O) حصول حالة قطع فيها عند الطاقات (0.01-8) MeV لأيونات الكاربون والاوكسجين.

1. INTRODUCTION

Stopping power is the rate of losing energy per unit distance in the material and is divided into two parts: electronic and nuclear stopping power [1]. Stopping power is the most important parameter of the energy loss process of energetic ions that is passing through matter. The energy loss of heavy ions is complicated because of the charge-exchange effect which leads to charge-state fluctuations [2]. The electronic stopping is caused by the interaction of ions with the target bound electrons [3]. The lost energy of the ions penetrating the material can occur due to a number of processes [4]. Excitation and ionization of the target atoms, capture of the electron, ionization or excitation of the projectile.

The aim of this research to study mass stopping power for the projectile's protons, carbon and oxygen ions in polymers (C_3H_3N, C_2H_4O) using Bethe and Bragg equations.

2. THEORY

The stopping power is defined as loss energy per distance in the target material which can be written as (-dE/dx) which is depending on the projectile charge and also on the target matter [5].The study of stopping power is one of the subjects which takes a large space in the study of physics scientists .These studies were theoretical and experimental by using different methods [6].

For compounds Bragg additively rule is found to work quite well. The rule says the mass stopping power for the substance containing several elements is taken to be equal to the weighted sum of the mass stopping power of the constituent atoms [7].

$$\left(\frac{-dE}{\rho dX}\right)_{com} = \sum_i \omega_i \left(\frac{-dE}{\rho dX}\right)_i \qquad (1)$$

where:

$$\omega_i = \frac{n_i A_i}{A_{comp}}$$

ω_i : the ratio of the weight of the elements in the compound

n_i : number of atoms of the j[th] kind of atoms in a compound or mixture

A_i: atomic mass of medium

ρ : the density of the medium

$\left(\frac{-dE}{\rho dX}\right)_{com}$: Mass stopping power of compound.

$\left(\frac{-dE}{\rho dX}\right)_i$: Mass stopping power for the elements in the compound.

Bragg rule is [8]:

$$\left(\frac{-dE}{\rho dX}\right)_i = \frac{\omega_1}{\rho_1}\left(\frac{-dE}{dX}\right)_1 + \frac{\omega_2}{\rho_2}\left(\frac{-dE}{dX}\right)_2 + \cdots \qquad (2)$$

The stopping power of charged particles can be calculated using Bethe equation (quantum mechanics) [9].

$$-\frac{dE}{dX} = \mathrm{K}\frac{Z_2 Z_1^2}{A\beta^2} L_{Bethe} \qquad (3)$$

Where:

$$L_{Bethe} = \ln\left[\frac{2m_e c^2 \beta^2}{1-\beta^2}\right] - \beta^2 - \ln < I >$$

$$K = 4\pi r_0^2 m_e c^2 = 0.307075$$

$$-\frac{dE}{dX} = 0.307075 \frac{Z_2 z_1^2}{A\beta^2} L_{Bethe}\left(\frac{MeV.cm^2}{g}\right)$$

r_0 : the classical radius of electron $\frac{e^2}{m_e c^2}$ $=2.818*10^{-15}$ m

m_e: the rest mass of electron =9.11*10^{-31} kg.

c : the speed of light in the vacuum =3*10^{8} m/sec

v : the speed of light in the target material

$m_e c^2$: rest mass energy of the electron = 0.511 MeV

Z : atomic number of target material.

z : atomic number of projectile

A : atomic mass of medium.

β : relative velocity. β = v/ c

I : the ionization potential of the medium in eV.

3. RESULTS AND DISCUSSION

The equations (1, 2 and 3) were programmed using MATLAB 2016. Table (1) illustrated the values of the stopping power for protons, carbon and oxygen ions in the polymers C_2H_4O and C_3H_3N. The result demonstrated the deviation of the present work from the experimental values of SRIM2013 program for carbon and oxygen ions in the polymers (C_2H_4O, C_3H_3N) as shown in figures (1,2,3,4) in energies less than (1) MeV where the stopping power is cut off that the reason for this parts attributed to low speed of particle so the stopping number (L_{Bethe}) is negative.

figures (5,6) showed a good agreement between the present work , SRIM2013 and PSTAR results at energies greater than (0.04) MeV in the polymers (C_2H_4O and C_3H_3N) the reason for correspond at energies greater than (0.04) MeV is due to Bethe equation is a quantum equation good at these higher energies (0.04) MeV for protons in the polymers (C_2H_4O and C_3H_3N), in figures (1,2,3,4,5,and 6) The correlation coefficient (r) is 0.90 to 0.98.

Table 1: illustrated the values of the stopping power for protons, oxygen and carbon ions in the polymers C_2H_4O and C_3H_3N

$\frac{-dE}{\rho dX} = \frac{\mathrm{MeV.cm^2}}{\mathrm{g}}$						
E(MeV)	Proton		Oxygen		Carbon	
	C_2H_4O	C_3H_3N	C_2H_4O	C_3H_3N	C_2H_4O	C_3H_3N
0.01	9012.39-	8719.16 -	75113995.92-	72919852.60-	29623848.1-	28797705.8-
0.04	449.86	438.17	12882050.06-	12617681.16-	4918400.56-	4831747.87-
0.045	604.02	587.21	11005399.70-	10791866.02-	4184046.16-	4116075.36-
0.06	826.98	802.61	7438304.29-	7317467.30-	2793892.64-	2759499.83-
0.07	880.6	854.31	6001027.15-	5915508.75-	2236704.81-	2214842.70-
0.08	900.72	873.62	4966920.25-	4905777.47-	1837313.52-	1823957.89-
0.09	902.72	875.42	4192385.49-	4148766.81-	1539235.31-	1531890.55-
0.1	894.63	867.48	3593892.79-	3563274.83-	1309689.10-	1306723.33-
0.15	807.3	782.57	1936039.82-	1937791.48-	679110.92-	686484.05-
0.2	717.71	695.63	1207308.30-	1220416.09 -	406091.44-	416596.93-
0.25	643.83	623.98	813990.22-	831795.03 -	260808.77-	272300.71-
0.4	494.14	478.85	308836.07-	329598.54 -	78669.25-	89916.31-
0.6	382.25	370.39	90918.67-	110301.46 -	3941.99-	13777.76-
0.8	314.83	305.05	7007.99 -	24493.80 -	22854.63	14233.76
1	269.35	260.98	32358.64	16540.16	34300.6	26631.9

2	161.94	156.9	75147.4	64395.85	42028.85	36995.26
4	94.77	91.81	67063.34	60265.9	33457.31	30340.59
6	68.66	66.52	56213.11	51126.75	27159.79	24847.82
10	45.46	44.04	42429.19	38957.64	22954.82	21096.13
15	32.66	31.64	32895.39	30358.58	19968.93	18404.52
20	25.82	25.01	27127.5	25106.29	15259.22	14122.29
30	18.55	17.97	20397.43	18938.19	12482.21	11579.36
40	14.69	14.23	16532.38	15378.23	9299.46	8650.25
50	12.29	11.9	13994.32	13033.78	7497.28	6985.05
60	10.64	10.3	12186.91	11361	6323.65	5898.06
70	9.43	9.13	10827.7	10101.24	5492.61	5127.12
80	8.51	8.24	9764.65	9114.88	4870.28	4549.1
100	7.19	6.96	8202.07	7663.25	4385.15	4098.09
200	4.43	4.29	4720.26	4420.53	3674.67	3436.89
300	3.47	3.36	3398.49	3186.23	2103.65	1971.66
400	2.99	2.89	2688.48	2522.31	1512.27	1418.8
800	2.3	2.23	1529.14	1436.67	1195.99	1122.77
1000	2.18	2.11	1277.24	1200.47	682.19	641.26

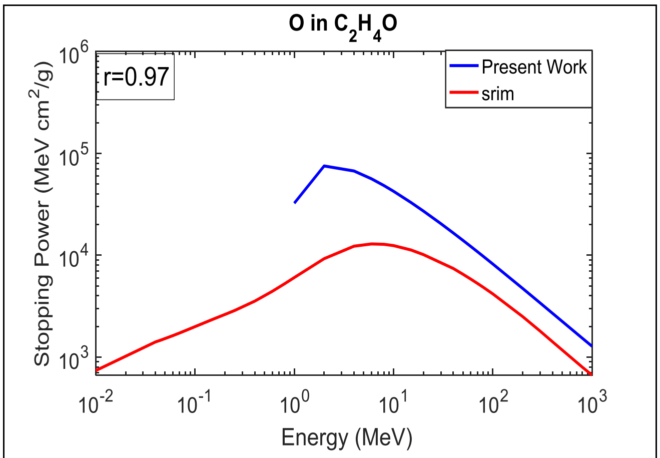

Figure 1: Comparison of the present work and SRIM2013 for stopping power of C_2H_4O as a function of projectile energy for oxygen ions.

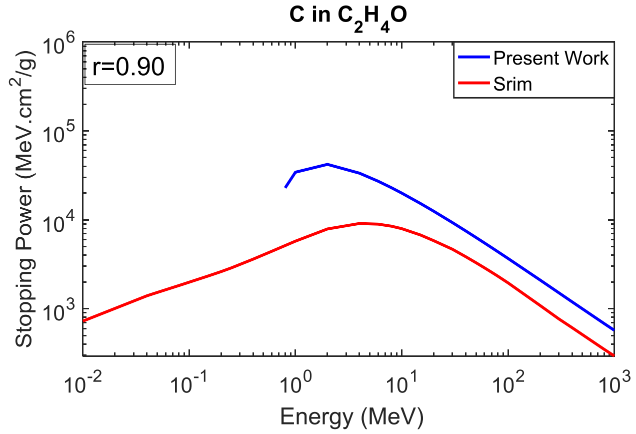

Figure 3: Comparison of the present work and SRIM2013 for stopping power of C_2H_4O as a function of projectile energy for carbon ions.

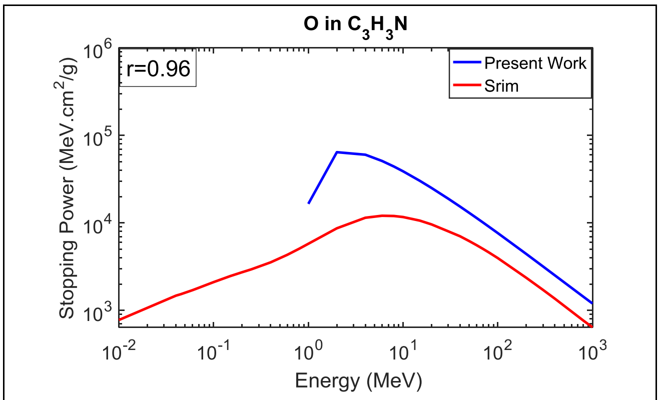

Figure 2: Comparison of the present work and SRIM2013for stopping power of C_3H_3N as a function of projectile energy for oxygen ions.

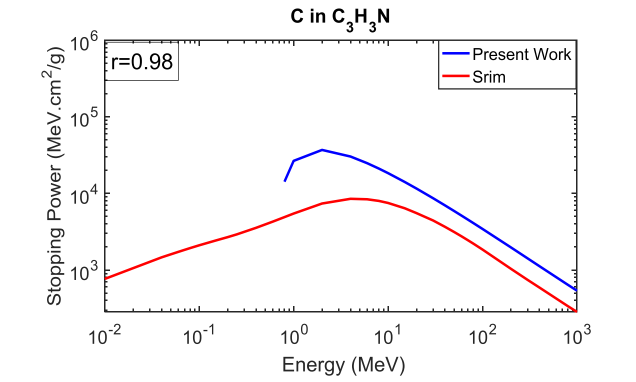

Figure 4: Comparison of the present work and SRIM2013 for stopping power of C_3H_3N as a function of projectile energy for carbon ions.

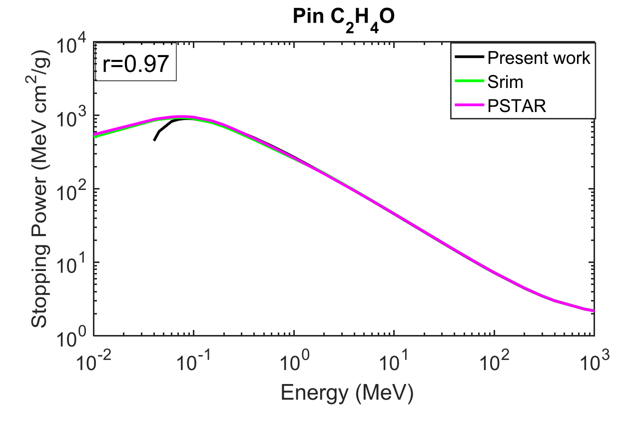

Figure 5: Comparison of the present work, SRIM2013 and PSTAR for stopping power of C_2H_4O as a function of projectile energy for protons.

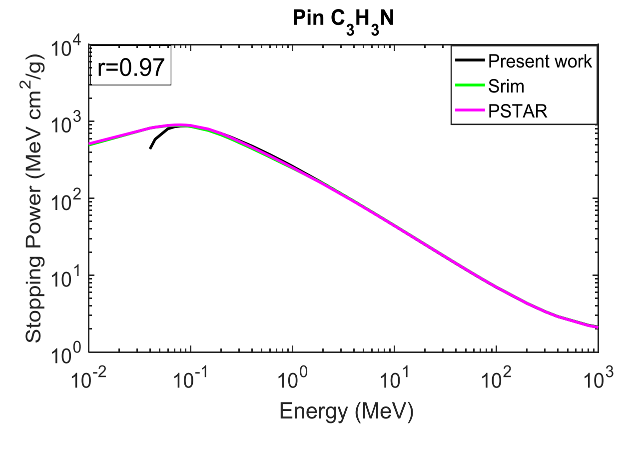

Figure 6: Comparison of the present work, SRIM2013 and PSTAR for stopping power of C_3H_3N as a function of projectile energy for protons.

4. CONCLUSIONS

1. We conclude that the Bethe equation (3) is suitable for the calculation of the electronic stopping power of protons in the studied polymers .
2. When calculating the stopping power of carbon and oxygen ions in studied polymers shows L_{Bethe} is negative in energy rang less than (1MeV).
3. From Table (1) we observe that the values of the stopping power for Carbon and Oxygen Ions in Polymers (C_2H_4O ,C_3H_3N) is negative in energy rang (0.01- 0.8) MeV.
4. We observe the correlation coefficient (r) is 0.90 to 0.98 .

It has applications in several important fields, including the field of studies and scientific research and the field of diagnosis and medical treatment

The output colored images produced by sine transformation are different than those produced by cosine transformation, in terms of the way the structure of the

5. REFERENCES

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