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Stopping power of Mylar for low-velocity ^{11}B, ^{12}C, and ^{16}O ions

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The energy loss and stopping powers of 1.0–6.0 MeV ^{11}B, ^{12}C, and ^{16}O ions in Mylar foil were determined in a transmission geometry. The experimental data were compared to the commonly used semiempirical theoretical predictions of Ziegler, Biersack, and Littmark and significant deviations were observed. The stopping powers were determined to an accuracy of 4%.

I. INTRODUCTION

The knowledge of energy loss and stopping power of heavy charged particles in various foils are important in the fields of applications involving heavy ions and theoretical studies. The experimentally determined stopping powers of heavy ions in compound foil material are very few. In the case of Mylar foils, energy-loss and stopping-power data at energies above the stopping power maximum exist (Räisanen and Rauhala[1–3]). For lower energies, we are unaware of any experimental data.

The semiempirical theoretical predictions by Ziegler, Biersack, and Littmark[4] (ZBL), which scale experimental information on the basis of the Brandt-Kitagawa theory,[5] are commonly used in cases where stopping powers are needed. For compounds such as Mylar, the correction for chemical bonding must be made empirically.[6] Due to the lack of experimental data the validity of the ZBL model for compounds at lower energies has not yet been justified.

The aim of this work is to measure the stopping powers of heavy ions at low energies in Mylar foil and to verify the ZBL predictions. Further, we supplement our systematic studies of stopping powers of heavy ions in solid targets.[7–11] The present data were obtained by means of a transmission technique.

II. EXPERIMENTAL PROCEDURE

The ion beams were generated by the 2×1.7 MV tandem accelerator of Peking University. The schematic experimental arrangement is shown in Fig. 1. A 150-nm gold film on a silicon substrate was used to scatter the ions incident from the accelerator. The heavy ions scattered by 150° penetrated a Mylar foil placed behind a 3-mm-diam collimator and in front of a silicon barrier detector. The Mylar foil was fixed on an aperture which could be moved up and down by a handle. The energies for ions directly coming from the gold scatterer, and for those having passed through the Mylar foil, were measured separately. The energy loss in the Mylar foil could then be determined by the shift of leading or rear edges of the energy spectra. The experimental data were collected by an S-88 multiparameter analyzer and an IBM mircocomputer.

To extract stopping powers from the energy-loss data, the area density of the Mylar was determined from energy-loss measurements of α particles in the foil. The

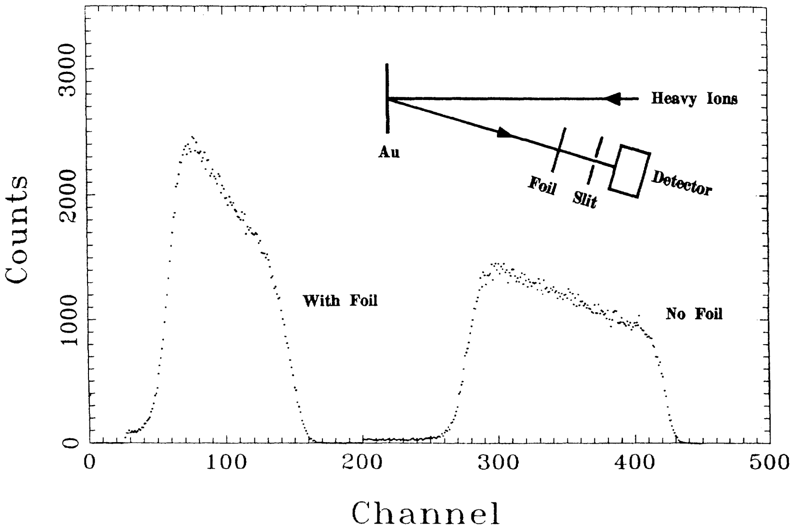


FIG. 1. Schematic experimental arrangement for measuring energy loss of ^{11}B, ^{12}C, ^{16}O in Mylar foils. A typical energy spectrum is also shown.

data of Rauhala and Räisanen[12] were used for this procedure.

III. RESULTS

To account for the nonlinear dependence of the stopping powers on ion energies near the stopping-power maximum, a small correction to the mean energy $E_{\mathrm{av}}=(E_{\mathrm{in}}+E_{\mathrm{out}})/2$ was used.[13] At lower energies, the stopping powers are linearly dependent on the ion energy, and no correction was needed. The extracted stopping powers are given in Table I and Fig. 2. The uncertainty of the determined values is about 4%. For comparison, previous experimental results[1–3] and the semiempirical predictions of TRIM-90 (Ref. 4) are also shown in Fig. 2.

IV. DISCUSSION

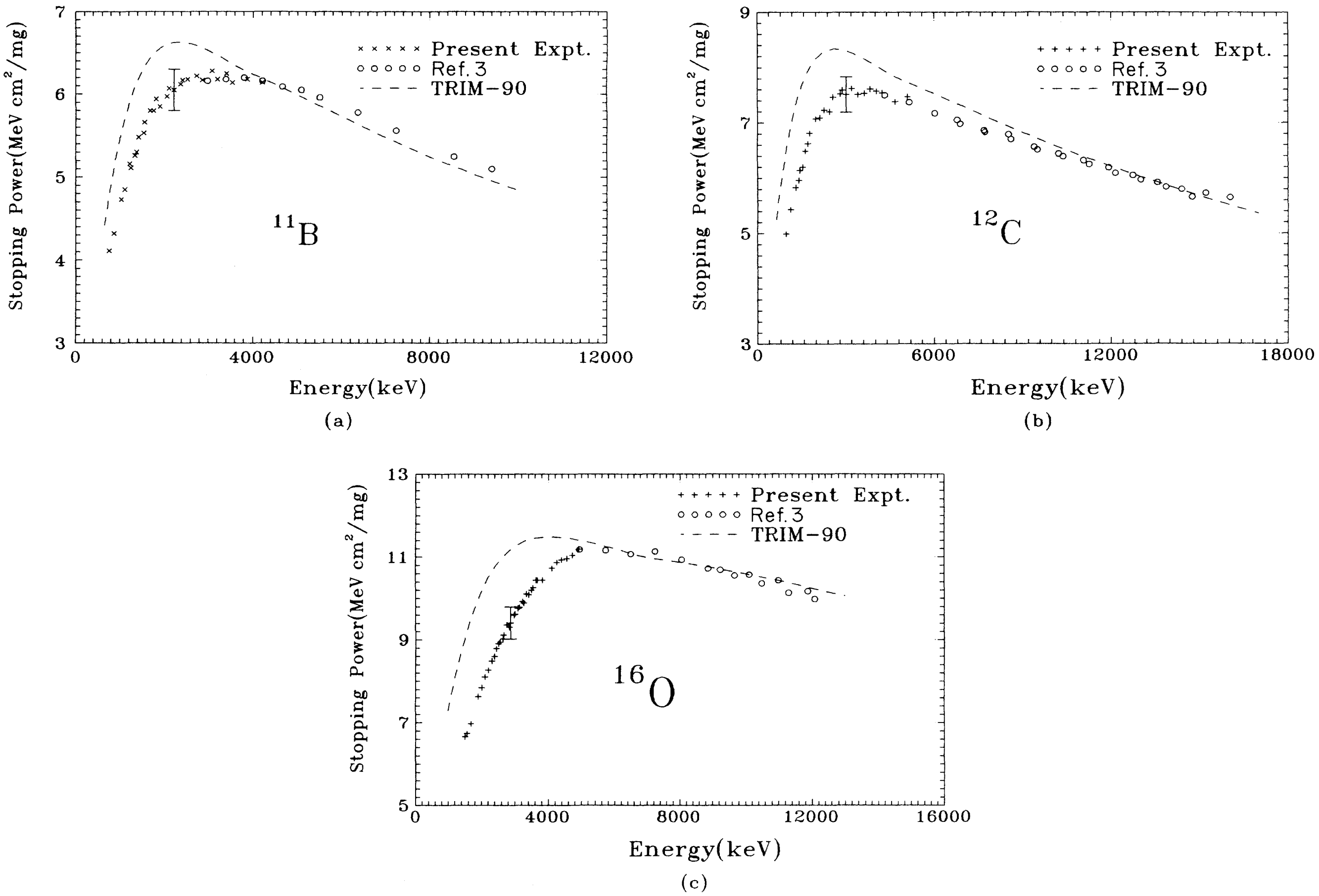
The stopping powers of ^{11}B, ^{12}C, and ^{16}O in Mylar foils show a remarkable discrepancy compared to the TRIM-90 predictions. The measured values are systematically lower than those of TRIM-90, as shown in Fig. 2, which means that the maximum appears at higher energies.

Good agreement was found at energies near the stopping-power maximum when we compared the present data to those of previous experiments[1–3] as shown in Fig. 2. At lower energies, especially below the stopping-power maximum no previous experimental data exist in the literature, to our knowledge. At these energies, no clear theoretical predictions are presented due to the ambiguity of the effective charge of heavy ions in solids.

Ziegler and Manoyan[6] developed a semiempirical mod-

TABLE I. Stopping powers of ^{11}B, ^{12}C, and ^{16}O in Mylar.

	B		C		O
E (keV)	dE/dX (MeV cm^2/mg)	E (keV)	dE/dX (MeV cm^2/mg)	E (keV)	dE/dX (MeV cm^2/mg)
757	4.11	986	4.99	1504	6.66
867	4.32	1144	5.43	1563	6.74
1033	4.73	1317	5.83	1683	6.98
1111	4.85	1424	5.96	1904	7.63
1216	5.16	1448	6.14	2006	7.85
1242	5.11	1543	6.20	2105	8.11
1342	5.26	1646	6.49	2206	8.27
1380	5.30	1729	6.62	2320	8.49
1424	5.48	1775	6.81	2392	8.60
1541	5.53	1991	7.07	2448	8.79
1559	5.66	2127	7.09	2510	8.91
1686	5.80	2276	7.23	2556	8.95
1767	5.80	2582	7.46	2645	9.03
1829	5.94	2830	7.52	2665	9.12
1917	5.85	2892	7.59	2770	9.37
2074	5.97	3027	7.51	2845	9.31
2120	6.07	3214	7.62	2880	9.41
2231	6.05	3422	7.51	2987	9.60
2381	6.12	3637	7.53	3010	9.62
2425	6.17	3836	7.61	3103	9.76
2541	6.18	4044	7.57	3138	9.79
2744	6.22	4244	7.54	3227	9.93
2873	6.17	4678	7.38	3276	9.89
3088	6.28	5101	7.47	3348	10.11
3211	6.18			3415	10.09
3415	6.25			3492	10.20
3549	6.14			3546	10.26
3882	6.18			3635	10.44
4217	6.14			3677	10.44
				3821	10.44
				3956	10.63
				3978	10.63
				4111	10.73
				4252	10.87
				4394	10.93
				4548	10.96
				4718	11.04
				4910	11.19



(a)

(b)

(c)

FIG. 2. Stopping powers of ^{11}B, ^{12}C, and ^{16}O in Mylar. The data points comprise both our data and the experimental data of Räisanen and Rauhala (Refs. 1–3). The semiempirical predictions by TRIM-90 are represented by dashed lines.

el based on Bragg's rule and chemical cores and bonds (CAB) to calculate the stopping power of ions in compounds. However, a phase effect was not considered reviewed by Thwaites.[14,15] According to experiments, the stopping-power values are larger in vapor than in the condensed phase. The present observation is consistent with Thwaite comments and one would expect a better agreement between the experiments and the semiempirical predictions if the phase effect had been considered in the CAB model.

No evidence for the dependence on charge state of the incident ion beam may be deduced within the experimental accuracy. This fact showed that the equilibrium charge state of heavy ions in solids is independent of that of the incident ions.[16]

In summary, the energy loss and stopping power of ^{11}B, ^{12}C, and ^{16}O in Mylar was experimentally determined using a transmission geometry. The data are systematically lower than the semiempirical predictions of TRIM-90.

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