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Summary

The effects of backing plates on the radiation dose received by thin nylon films were calculated with a recently developed multilayer electron transport code. The film dose increased with increasing atomic number of the backing plate material. The estimated dose could be off by a factor of 2 or more if the backing plate was ignored in the calculations.

Introduction

The advantages of using highly cross-linked organic polymers to bind graphite fiber composites are well recognized and these polymers are projected to play an important role in future construction of space facilities. Despite the enthusiasm for these materials, questions remain regarding their long-term stability in the space environment for some applications (ref. 1). Clearly, material study and testing are required before committing these materials to specific space applications. Unlike crystalline materials, polymers are sensitive to the rearrangement of specific chemical bonds, and nuclear displacement is thought to play a minor role. This sensitivity to chemical bond changes makes the damage thresholds for highly cross-linked polymers quite low, and the damage shows no characteristic healing, as compared with crystalline materials. Consequently, a radiation testing program is in progress to study ionizing radiation effects on polymer materials (refs. 2 to 4).

During radiation testing in particle accelerator laboratories, heat must be transported away from the target area. Hence, the typically thin polymer target films are mounted on a metal backing plate which is maintained at a constant temperature. The presence of the backing plate perturbs the local radiation fields and must be taken into account in order to properly define the film exposure. The importance of such effects depends on the thickness of the polymer film, the thickness and composition of the backing plate, and the energy of the electron beam.

In this report, the calculated dose received by a nylon 6,6 film of 0.98-mil thickness is presented as a function of the backing material. The dose is calculated with a multilayer electron transport code (ref. 5) based on the most recent cross section data of Berger and Seltzer (ref. 6). The dose profile within the nylon film is also presented for several backing materials and various electron energies.

Details of Calculations

The geometric arrangement for the present calculations is shown in figure 1. The 0.98-mil nylon film was presumed to be exposed to a uniform fluence of monoenergetic electrons incident from the left. The backing plate was assumed to be of an elemental material of infinite extent. The electrons were perpendicularly incident on the exposed face. In each case, 10 000 electron histories were followed in the calculations.

The composition of the nylon 6,6 film is given in table 1. Table 2 gives the density of the backing materials used. The range of electron energies (0.070 MeV to 2.0 MeV) covered those important to space radiation effects.

The calculation model (ref. 5) takes into account all the prime physical processes. The main interaction of the electrons with the material is in atomic-molecular collisions, in which energy is transferred to orbital electrons of the material. The amount of energy transferred per collision is generally quite small, although the collision cross sections are very large. Thus, one may treat the atomic-molecular collisions in a continuous slowing down approximation (CSDA) similar to the motion of a macroscopic object through a viscous fluid. Deviations of the electron trajectories from the CSDA motion are treated on a statistical basis since they appear as rare isolated events. These isolated events include the production of delta rays (energetic secondary electrons), coulomb scattering from the atomic nucleus (Mott scattering), inner shell vacancy production, bremsstrahlung production, and pair production. A host of secondary processes result which are also treated in detail in the calculations. These include X-ray production, Auger electron transitions, positron annihilation, photoelectric transitions, photoelectric absorption, and Compton scattering.

Results and Discussion

The energy absorbed in the nylon films is shown in figure 2 for the five backing materials. The first data point at $Z = 0$ (where Z represents the atomic number) is for the unbacked sample. There is an apparent smooth transition in the dose as the atomic number of the backing material is changed. This is related to the multiple coulomb scattering of the backing plate nuclei, which increases with atomic number. The effect is less noticeable at higher energies since relativistic effects make the scattering predominately forward, and pair and bremsstrahlung production become more important.

The dose profile within the film is shown in figures 3 to 7. At 0.070 MeV the backscattered electrons are most important near the interface of the film and the backing plate. The backing plate hardly affects the dose at the front surface of the film because the electron range at this energy is nearly equal to the thickness of the nylon film (table 3). After additional energy is lost in scattering from the backing plate, insufficient energy is left for the electron to reach the front surface. This is less true at 0.10 MeV, as shown in figure 4, where the backing plate composition significantly affects the dose at the front surface.

At higher energies the dose is relatively uniform throughout the film. The backing material merely raises the dose uniformly to higher levels. The estimated dose could be off by a factor of 2 or more if the backing plate was ignored in the calculations.

The backscattering effect also depends on the thickness of the backing plate. This is demonstrated in figures 8 and 9, where results are shown for several gold backing plate thicknesses.

Concluding Remarks

The effects of backing plates on the dose received by 0.98-mil nylon 6,6 films were calculated for monoenergetic electrons with energies of 0.070, 0.10, 0.50, 1.0, and 2.0 MeV. The results show that the additional dose received by the films increased with increasing atomic number of the backing plate material. The dose profiles indicate that nonuniform dose distribution within the sample resulted when the sample thickness was comparable to the range of the electron. The dose profile for 0.070-MeV electrons shows a marked increase in the dose at the interface region. The effect of the backing plate thickness on the dose was demonstrated by using gold as the backing plate material.

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Table 1. Composition of the Nylon 6,6 Film

[Film density of 1.14 g/cm^3]

Element	Atomic number, Z	Number of atoms	Mass, percent
H	1	22	9.73
C	6	12	63.72
N	7	2	12.39
O	8	2	14.16

Table 2. Density ρ and Atomic Number Z of Backing Plates

Backing plate material	Atomic number, Z	ρ, g/cm^3
C	6	2.25
Al	13	2.70
Zn	30	7.14
Ag	47	10.5
Au	79	19.3

Table 3. CSDA Ranges of Electrons in Nylon 6,6

Energy, MeV	Range, g/cm^2
0.070	7.67×10^{-3}
.10	1.42×10^{-2}
.50	1.76×10^{-1}
1.0	4.38×10^{-1}
2.0	9.8×10^{-1}

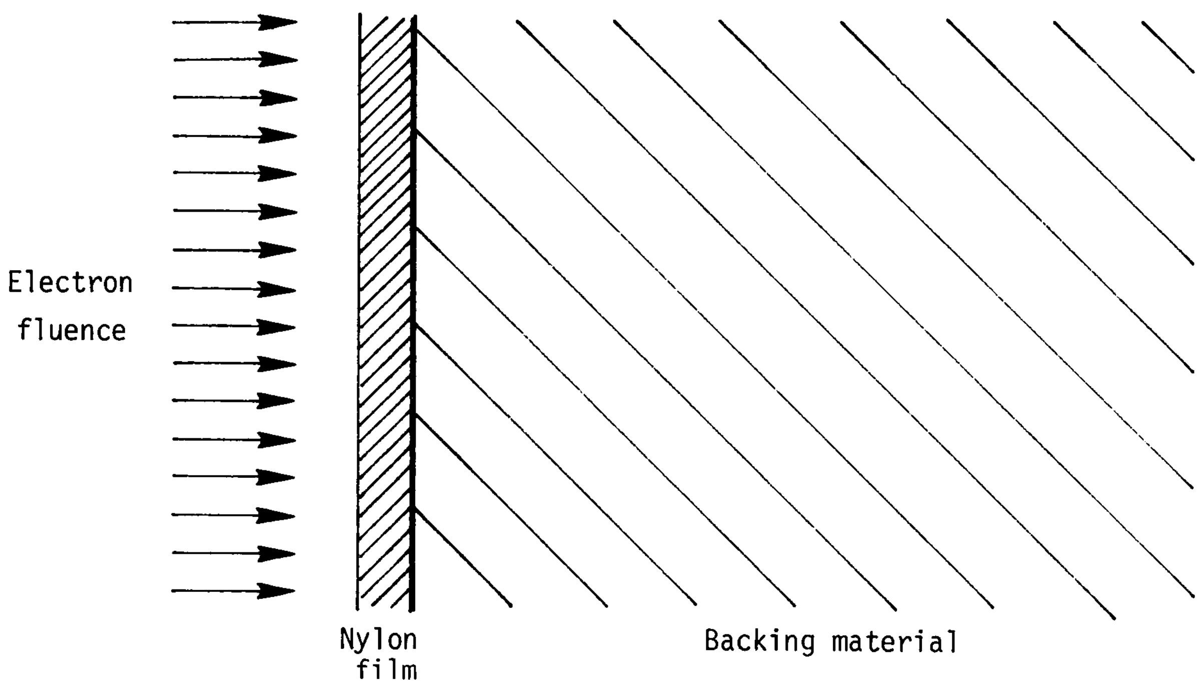

Figure 1. Geometric arrangement for present calculations.

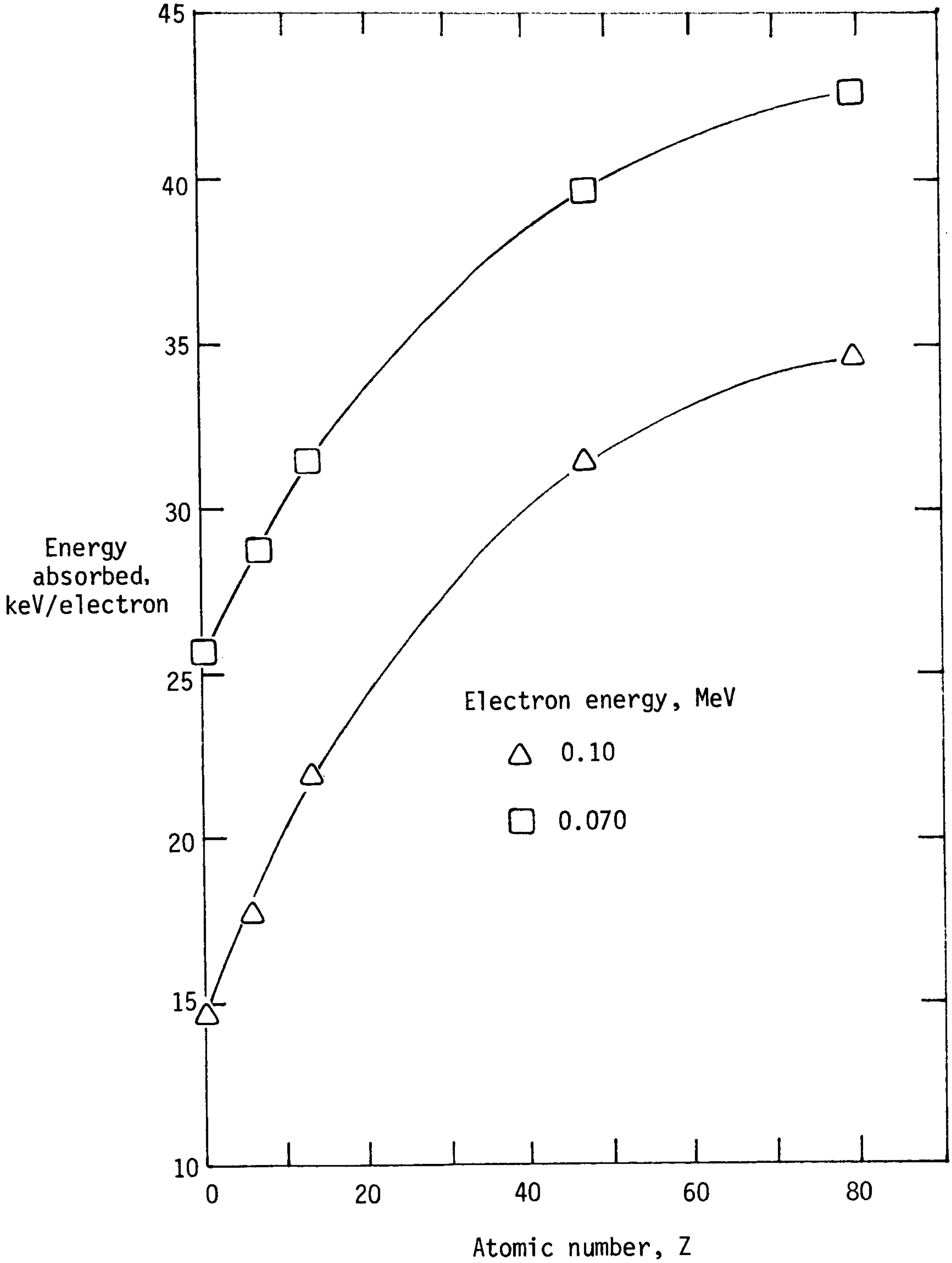

Figure 2. Energy absorbed in nylon 6,6 films as a function of electron energies and atomic number of backing materials.

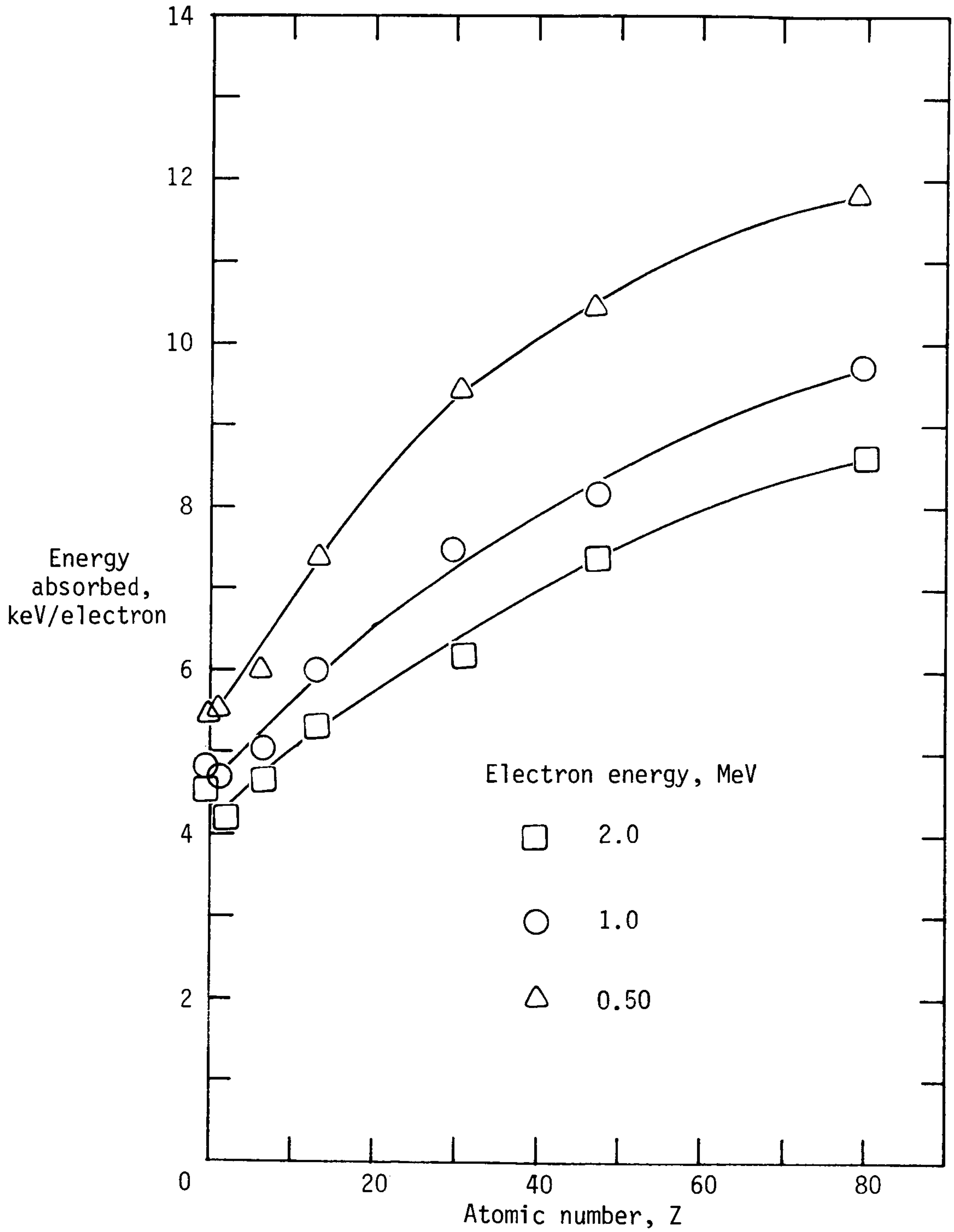

Figure 2. Concluded.

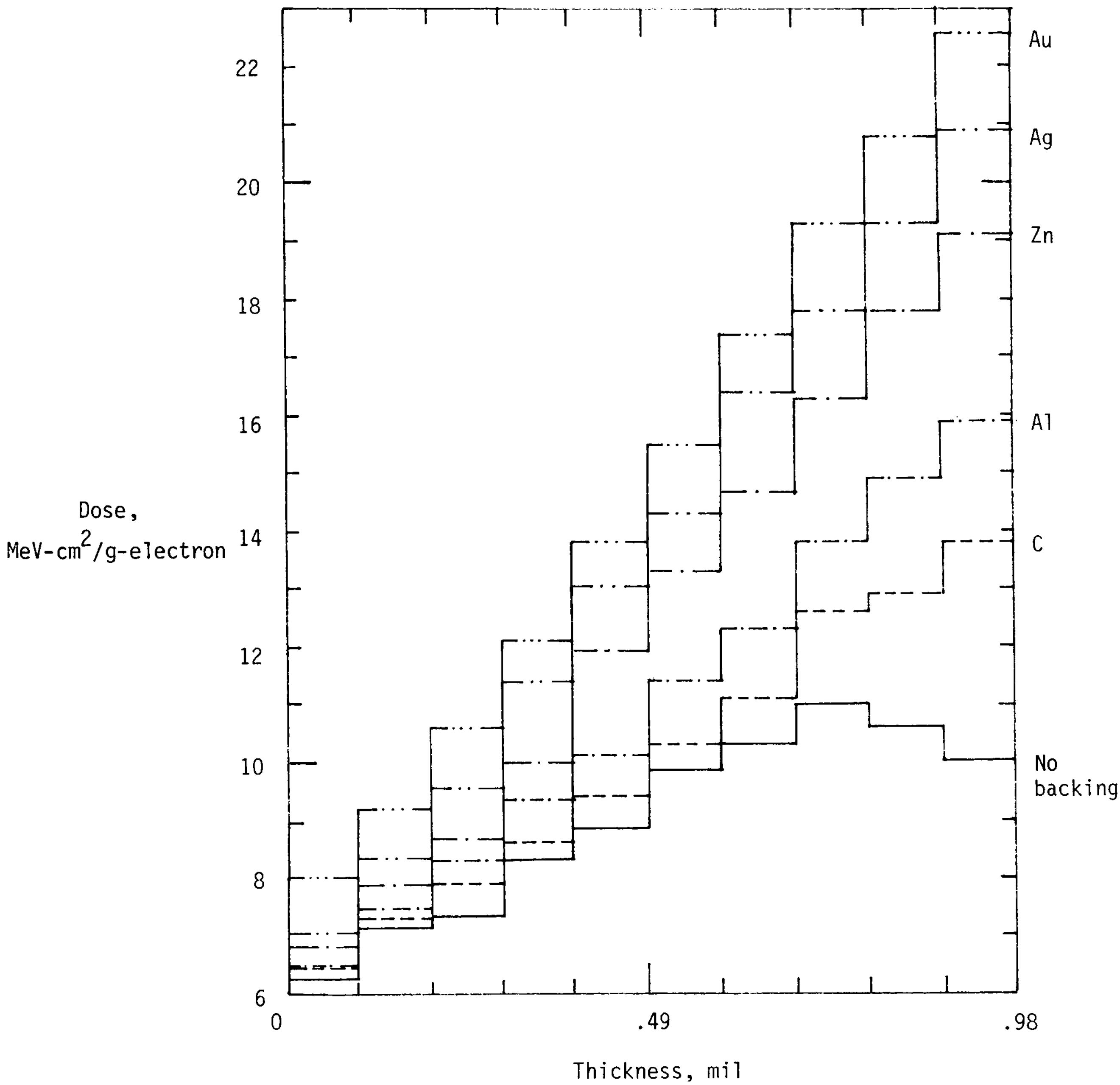

Figure 3. Dose profile due to 0.070-MeV electrons in 0.98-mil nylon 6,6 films with various backing materials.

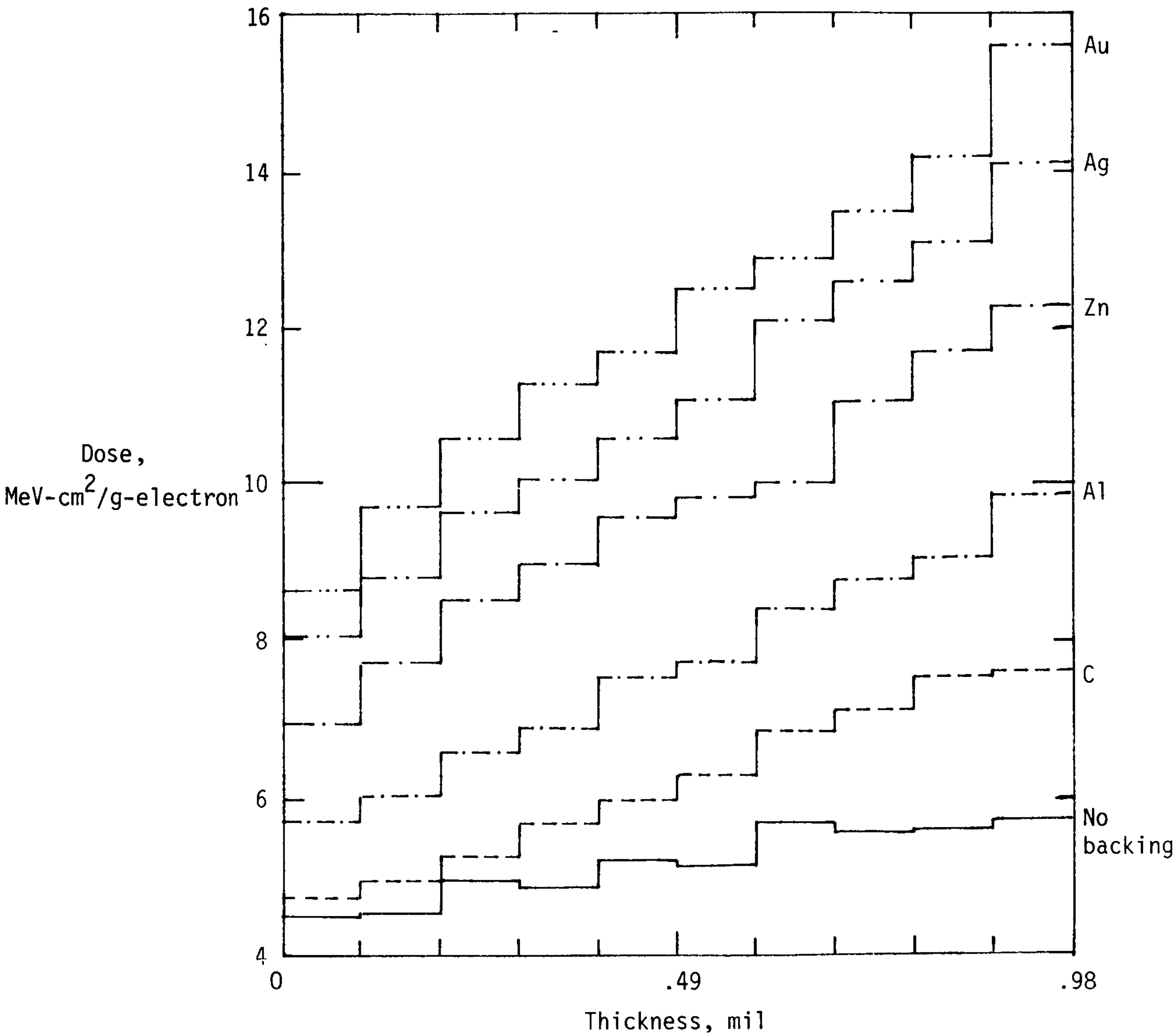

Figure 4. Dose profile due to 0.10-MeV electrons in 0.98-mil nylon 6,6 films with various backing materials.

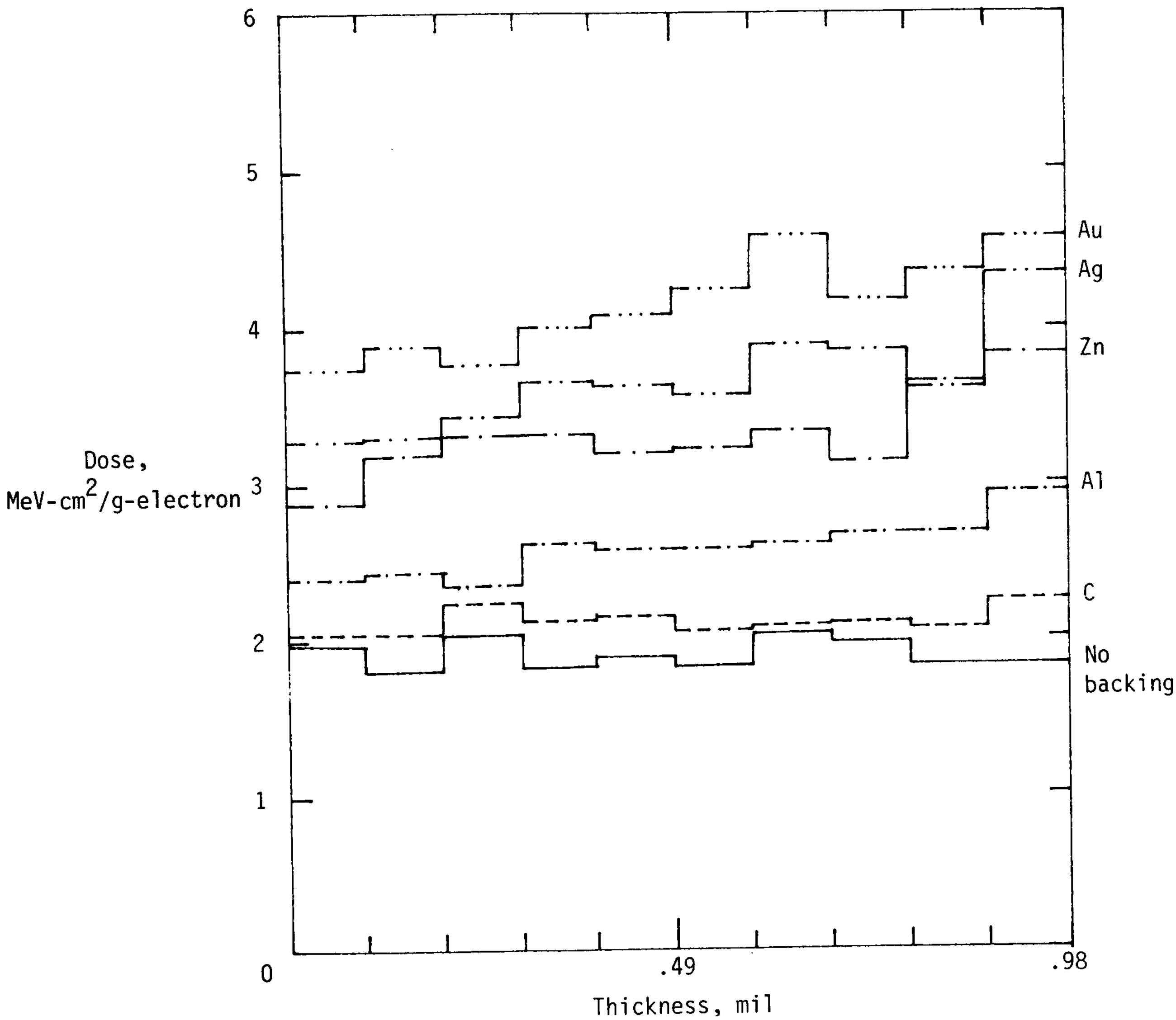

Figure 5. Dose profile due to 0.50-MeV electrons in 0.98-mil nylon 6,6 films with various backing materials.

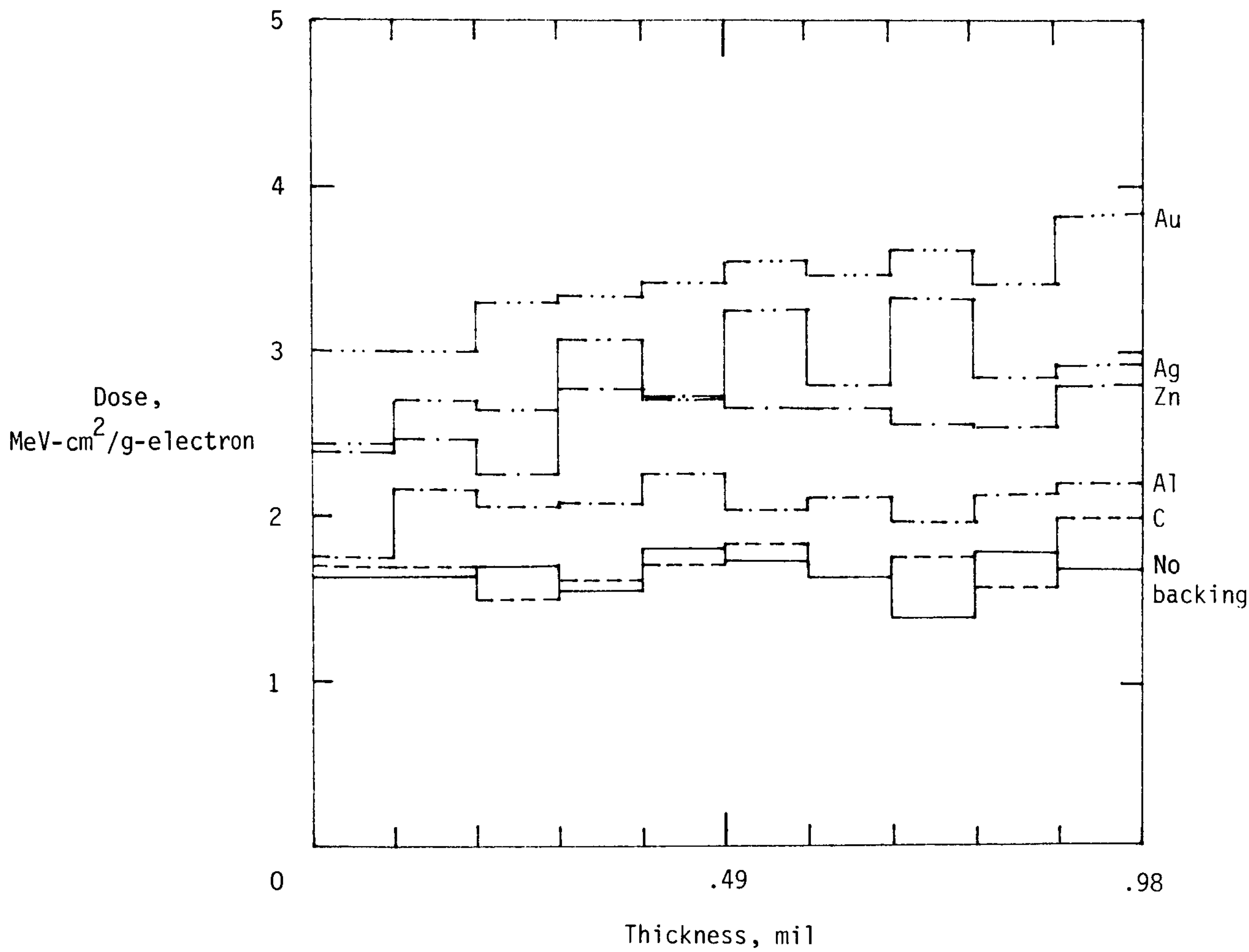

Figure 6. Dose profile due to 1.0-MeV electrons in 0.98-mil nylon 6,6 films with various backing materials.

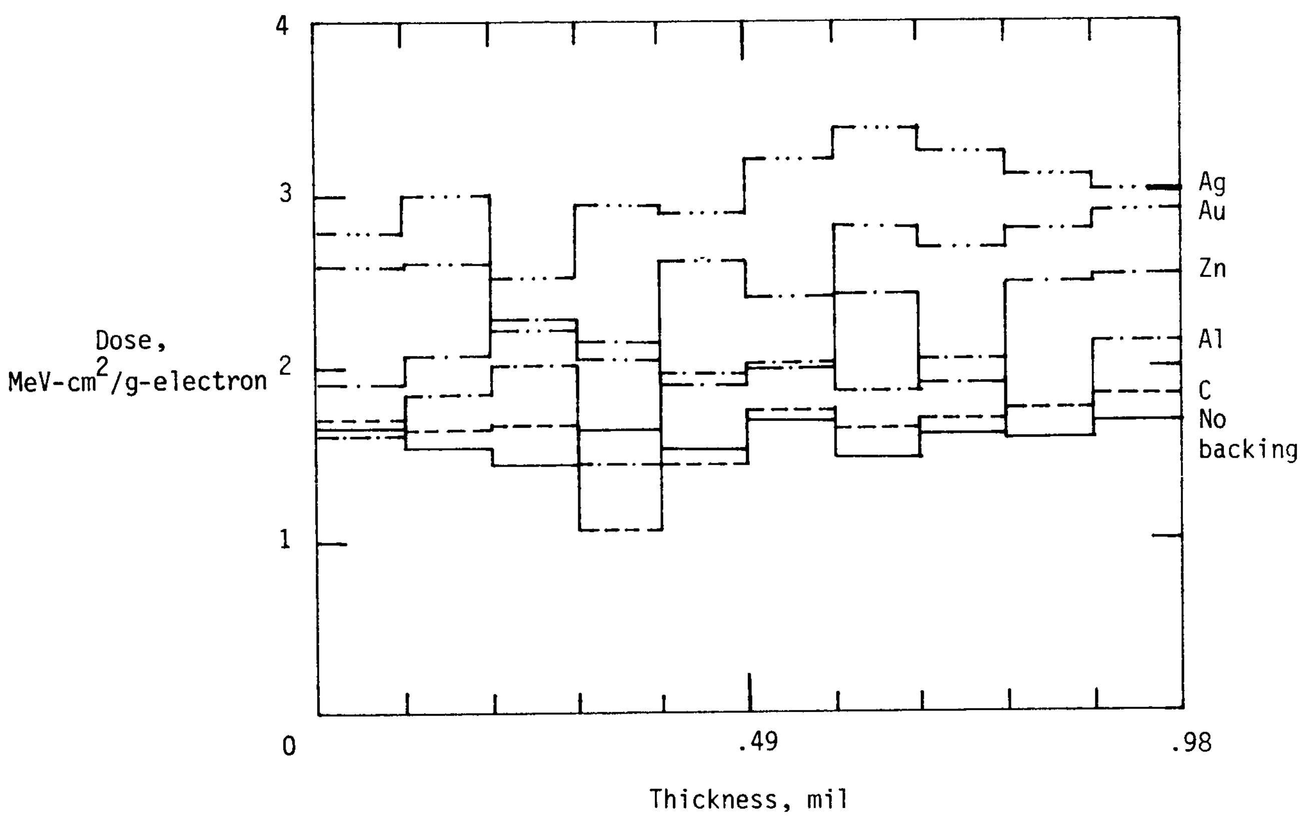

Figure 7. Dose profile due to 2.0-MeV electrons in 0.98-mil nylon 6,6 films with various backing materials.

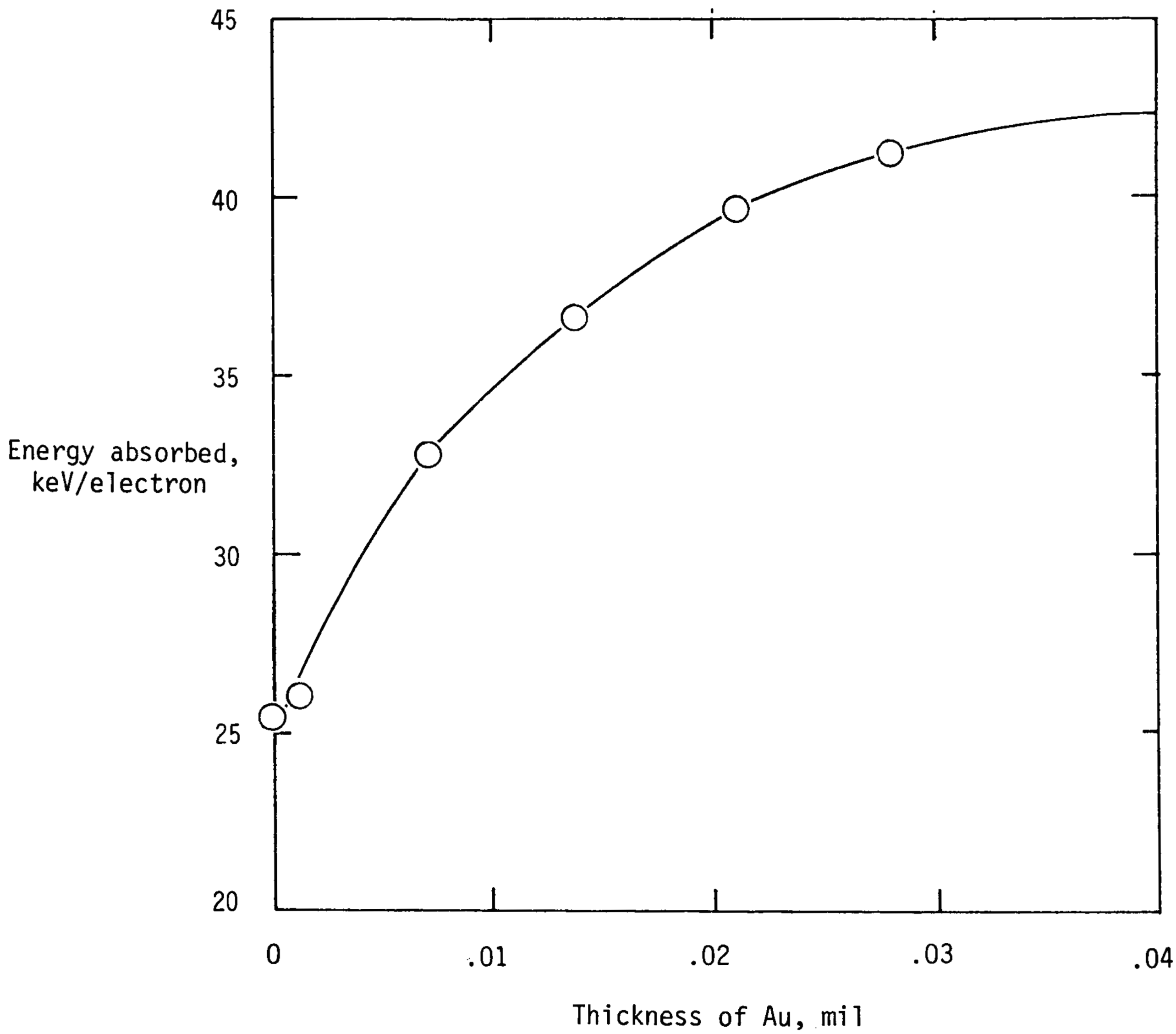

Figure 8. Energy absorbed due to 0.070-MeV electrons in 0.98-mil nylon 6,6 films backed by various thicknesses of gold plates.

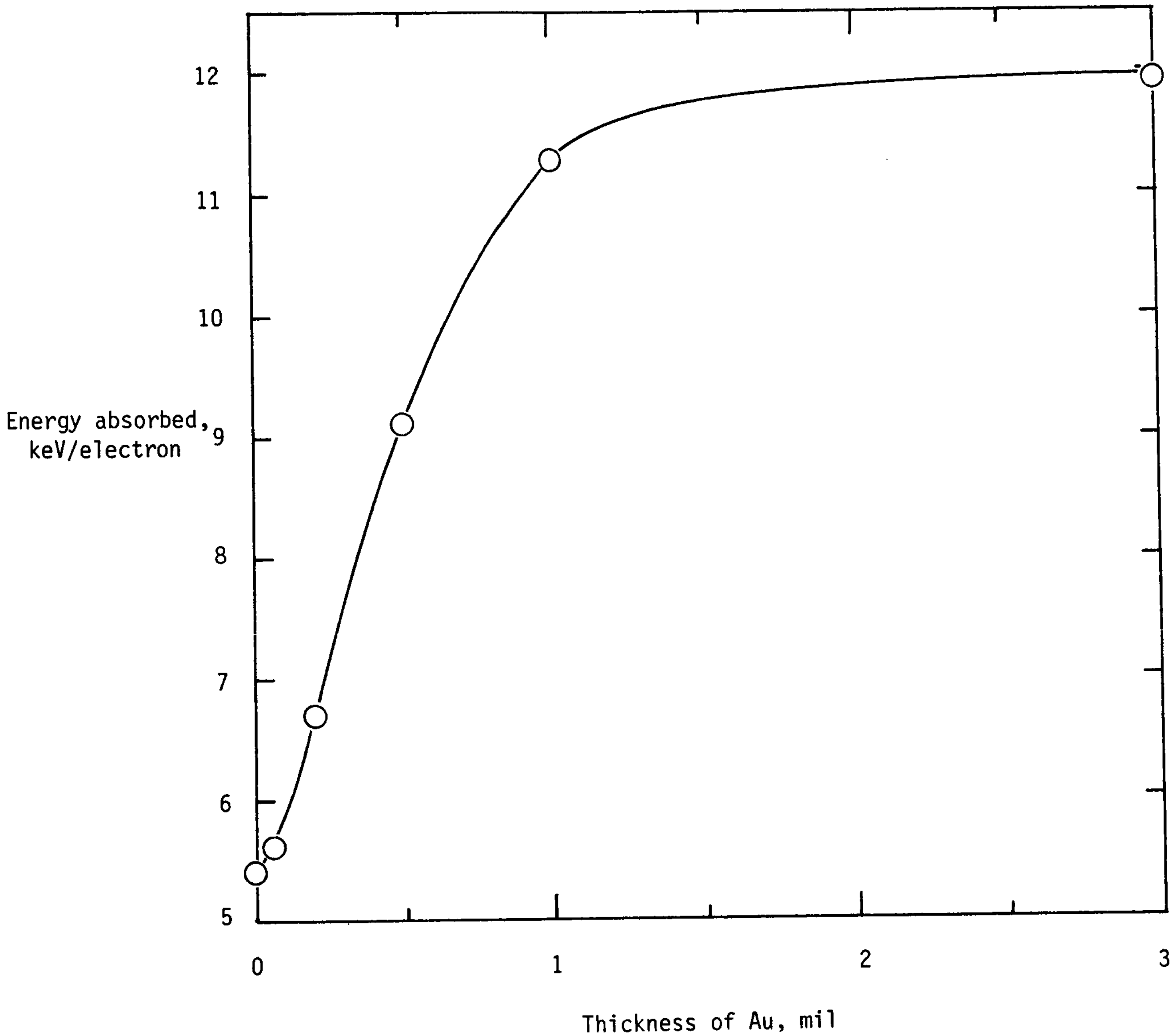

Figure 9. Energy absorbed due to 0.50-MeV electrons in 0.98-mil nylon 6,6 films backed by various thicknesses of gold plates.

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16. Abstract
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