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P-1

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3

# **PROPX an X-ray Manipulation Program**

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## **ABSTRACT**

An interactive micro-computer program that performs some manipulations on an input x-ray spectrum is introduced and described. The program is used to calculate the effect of absorption by filters, transmission through filters, responsivity of photocathodes, responsivity of absorptive detectors, folding of responses, plotting of cross sections, and calculation, as a function of electron temperature, of the response due to a bremsstrahlung spectrum. Fluorescence from the targets is not included. Two different x-ray libraries are offered, one covers the x-ray range 30-10,000 eV with 288 energy points, and the other covers the energy range 10 eV to 1 MeV with 250 energy points per decade.

## I. INTRODUCTION

The diagnosis of many kinds of plasmas requires the spectral resolution of the x-rays that are emitted from some region of the plasma.<sup>1,2</sup> Spectral selection invariably requires some type of filtering of the emitted x-rays, followed by detection. The detector may have some spectral sensitivity in the x-ray region of interest. The most commonly used x-ray selective elements are: thin filters, reflective elements, energy absorbing detectors, photoemissive detectors, photoconducting detectors, and photographic film. With such a variety of detectors, filters and their combinations, the task of designing a system by trial and error becomes tedious. A small and adaptable computer program is needed that can simulate many of the experimental conditions and that uses the best available x-ray data. With the proliferation and availability of inexpensive personal computers it was felt that a simple, portable, and fast program that can fit, with all of its data files, on the smallest exchange medium ( a 3.5 inch 360 kbyte disk) would be very useful.

The requirement led to the use of the most modern computer language that is: inexpensive, readable, widely available, fast, structured, and that is available on both the IBM and the Macintosh computing platforms. Thus the QuickBasic language [QB] ,now available with every Disk Operating System Version 5 for the IBM platform, was chosen. It is hoped that a simple porting of the IBM version to the Macintosh environment would be easy to perform.

## II. GENERAL DESCRIPTION

The program has three general functions; the selection of a data base, the choice of operation on a material or a combination of materials, the folding of the calculated

response with an input spectrum, and the outputting of the results of the calculations either to the screen or to a file.

*Data Bases:*

Two data bases are being offered. The first, is a small tabular data base that is based on the work of Henke.<sup>3</sup> The data base consists of absorption cross sections that are tabulated at 288 energy points distributed on a logarithmic grid between 30 eV and 10,000 eV. The second, is the Sandia data base that consists of analytic fits to the x-ray data with different fitting coefficients within each absorption edge of the material.<sup>4</sup> The data was implemented by choosing the energy attenuation cross sections, rather than the total absorption cross sections, since they are more appropriate for simulating the experimental conditions where energy is measured. The second data base is implemented with 1250 energy points logarithmically distributed between 10 eV and 1 MeV with 250 points per cycle. This choice of number of data points, can be changed to increase the number of points at the expense of some loss in the speed of response. The two data bases are in general agreement above 100 eV. Below 100 eV, the Sandia data base is more accurate and fits most of the experimental data, thus reproducing the edges well. However, using the Henke data base offers great speed advantage over the Sandia data base.

*Operations:*

The program was written to analyze a subset of the x-ray elements that are usually used. A list of the different operations that can be performed are listed in table-1. The general syntax of the input in response to an operation is:

$$OZ, X u <cr>$$

where O is a single character that represents a desired operation [T,D,C,S,E,H]. Z is an integer that represents the nuclear charge of the element of interest. If the x-ray element

is made from one element then one inputs the nuclear charge of the element Z between 1 and 94. If the foil is made of many elements, then one repeats the procedure with different Zs and different thicknesses. For the case of compound material foils that are used often, a compound definition file is accessed from a submenu by choosing a Z that is greater than 100. Included with the program is an ASCII editable file with a predefined selection of commonly used compounds, Table 2. X is an input that represents the thickness of the filter or detector, and u is the optional input that represents the unit of the thickness[A,M,N]. The default unit is the micrometer and the default material density is read from an ASCII based table. A,M,and N represent the angstrom, micrograms/cm<sup>2</sup> and nanometer units respectively.

The transmission [T], detection [D] and photoresponse calculations [C] assume that the input spectrum is a flat spectrum. The photocathode response calculation deserves a special note. The calculations are based on a model for the front and rear responses of the photocathode pack and requires a knowledge of; t, the thickness of the material, ρ, the density of the material, μ, the energy mass absorption coefficient of the material, and λ<sub>S</sub>, the electron mean free path in the material<sup>5,6,7</sup>:

$$Q_f = K \mu \rho \lambda_S E \tanh(t / \lambda_S)$$

$$Q_r = K \mu \rho \lambda_S E \tanh(t / \lambda_S) \exp(-t / \lambda_S)$$

Q<sub>f</sub> and Q<sub>r</sub> are the front and rear quantum efficiencies of the material, in electrons/photon, at photon energy E. The mean free path for few materials has been measured, and the yield for other targets have been presented by Henke et al.<sup>5</sup> relative to the yield of gold. To calculate the photocathode yield of material x, it was assumed that the target thickness was at least three times the electron mean free path, and hence the electron yield was not

sensitive to the mean free path. For that "thick" photocathode the quantity  $K\lambda_S$  was computed from the data<sup>5</sup> as follows:

$$(\mu \rho K \lambda_S \tanh(t / \lambda_S))_X = y_X (\mu \rho K \lambda_S \tanh(t / \lambda_S))_{Au}$$

$$L = (K \lambda_S \tanh(t / \lambda_S))_X = y_X (K \lambda_S \tanh(t / \lambda_S))_{Au} (\mu \rho)_{Au} / (\mu \rho)_X$$

$$Y_f = Q_f / E = L \mu \rho$$

$$Y_r = Q_r / E = L \mu \rho \exp(-t / \lambda_S)$$

where  $y_X$  is the total yield relative to gold, measured at some energy.  $Y_f$  and  $Y_r$  are the front and rear responses in electron per unit energy. The quantity  $L$  was entered in the COMPOUNDS file, and was assumed to change little with incident photon energy. If a new material is desired, then the COMPOUNDS file has to be modified for the new material. The operation on an external spectrum is performed using the [E] command. This allows an external file, in ASCII, to be convoluted with the computed response. The effect of using these commands is cumulative, and some of the operations can not be undone without selecting a new run. A useful feature, the [S] command, allows for displaying the energy absorption cross section itself. The [H] command gives a concise summary of the commands, its syntax, and some examples.

#### *Manipulations:*

After a response file is generated, the menu offers other choices: New calculations, File output, Screen plot versus Energy, Screen plot versus wavelength in Angstroms, Typing to the screen, Convolving with a 1D or a 3D bremsstrahlung spectrum, or Modifying the filter/detector pack. The convolution generates two output ASCII files that contain the convolution at 300 different electron temperatures between 100 eV and 30 keV.

### *Screen Plots:*

The Screen plot command generates a graphics plot in the high resolution EGA screen mode of the display. This mode is chosen for maximum compatibility with existing computing platforms. The display menu allows for simple manipulations of the graph display such as rescaling of the x and y axes, and the plotting of the data on logarithmic axes. Overlaid on the display is an up-to-date history of the operations used to generate the plot.

## **III. OPERATIONS**

As an example for the operation of the program, the response of a silicon-diode detector is calculated and displayed in Fig. 1 where the Henke data base is used. The detector is filtered by a 5  $\mu\text{m}$  aluminum foil. The detector has a thin .75  $\mu\text{m}$  thick layer of silicon oxide, and a 125  $\mu\text{m}$  sensitive depth. Notice that the output screen shows the input data at the top in the form, with the sequence of operations preserved. The response of the detector to the bremsstrahlung spectrum from a 1-dimensional and a 3-dimensional hot electron distributions is shown in Fig. 2. The unit of response is arbitrary, but one usually uses the ratio of the responses of different detector filter pairs to measure the hot electron temperature see Fig. 3 for an example. In Fig. 3, the response of a silicon diode with a 20  $\mu\text{m}$  copper channel and a 100  $\mu\text{m}$  is shown with the ratio of the channel output. The ratio is seen to be sensitive to the hot electron temperature as well as to the dimensionality of the distribution.

Another example of the applicability of the program is the calculation of the response of a streak camera photocathode using the Sandia data base. The photocathode is made of three layers. Starting from the direction of the x-ray source; a 3000 Angstrom Polypropylene filter that faces the x-ray source, a 250 angstroms layer of conductive

Aluminum, and lastly, a 1000 Angstroms of Potassium Iodide that faces the streak camera grid. This is an example of a photocathode that is used in the transmission mode [ a rear photocathode]. The result of the calculation is displayed in Fig. 4.

#### **IV. SUMMARY**

A computer program for study and prediction of the behaviour of simple x-ray elements has been described. The program uses the latest and most up-to-date x-ray data for its calculations. In the future, reflective x-ray elements and x-ray sensitive film responses will be added to the list of allowed x-ray elements.

#### **V. ACKNOWLEDGEMENTS**

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## FIGURE CAPTIONS

FIG. 1. Calculated response of a Silicon Pin Diode with a 125 micron sensitive depth, a .75 micron silica window, and filtered by a 5 micron thick aluminum filter. The Henke data base was used.

FIG. 2. Calculated relative output from the Pin Diode of Fig. 1 when observing the bremsstrahlung radiation from a 1D or a 3D maxwellian hot electron distribution.

FIG. 4. Calculated ratio [dashed line] of the response of a silicon-diode copper-filtered channel [dotted line] to that of a silver-filtered channel [continuous line], as a function of hot electron temperature and dimensionalities of the distribution. Figures A and B correspond to a 1D and a 3D distributions respectively.

FIG. 3. Calculated response of a Potassium Iodide (KI) photocathode used in the transmission mode. The KI is deposited on a conductive aluminum layer and supported by a 3000 Angst. thick polypropylene foil.

## **TABLES**

**Table 1. An example of the list of predefined compounds format.**

**Table 2. A list of the allowed operations and their short cuts.**

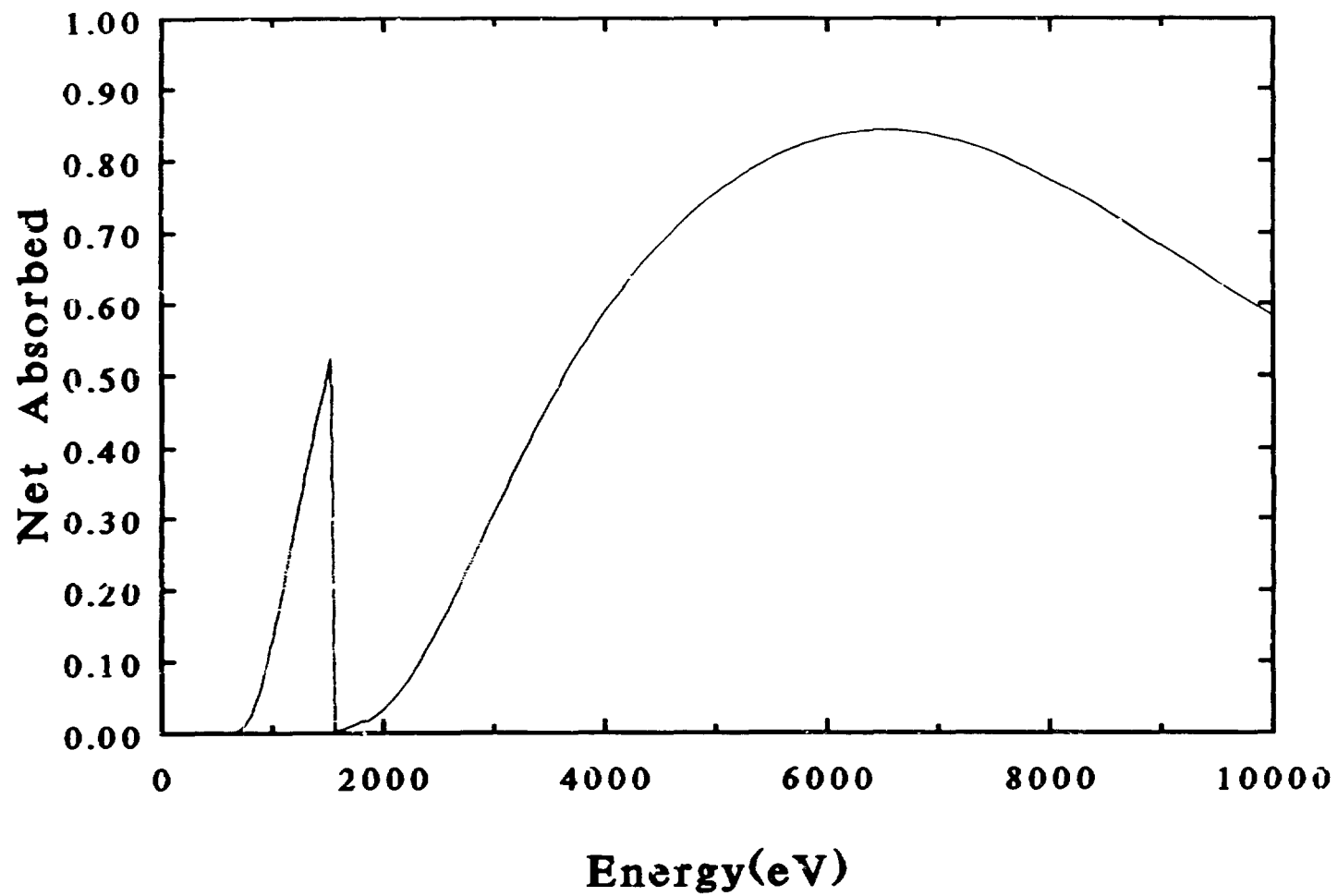
**Table 1**

<b>Name</b>	<b>Operation</b>
T	Transmission of filter
D	Energy Absorbing detector
C	Photocathode yield
S	Plot of raw cross section
E	Convolve with an external file

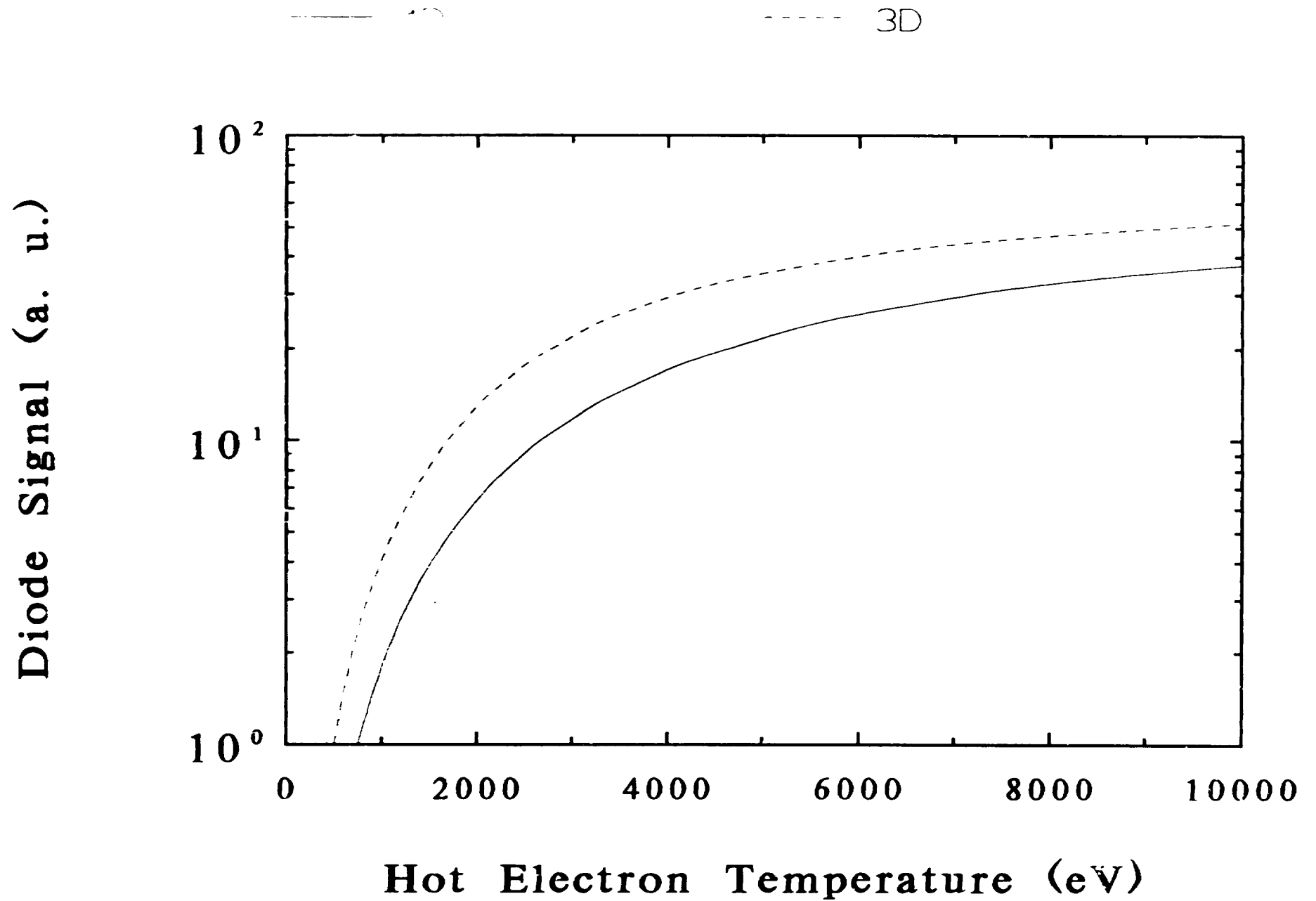
Table 2

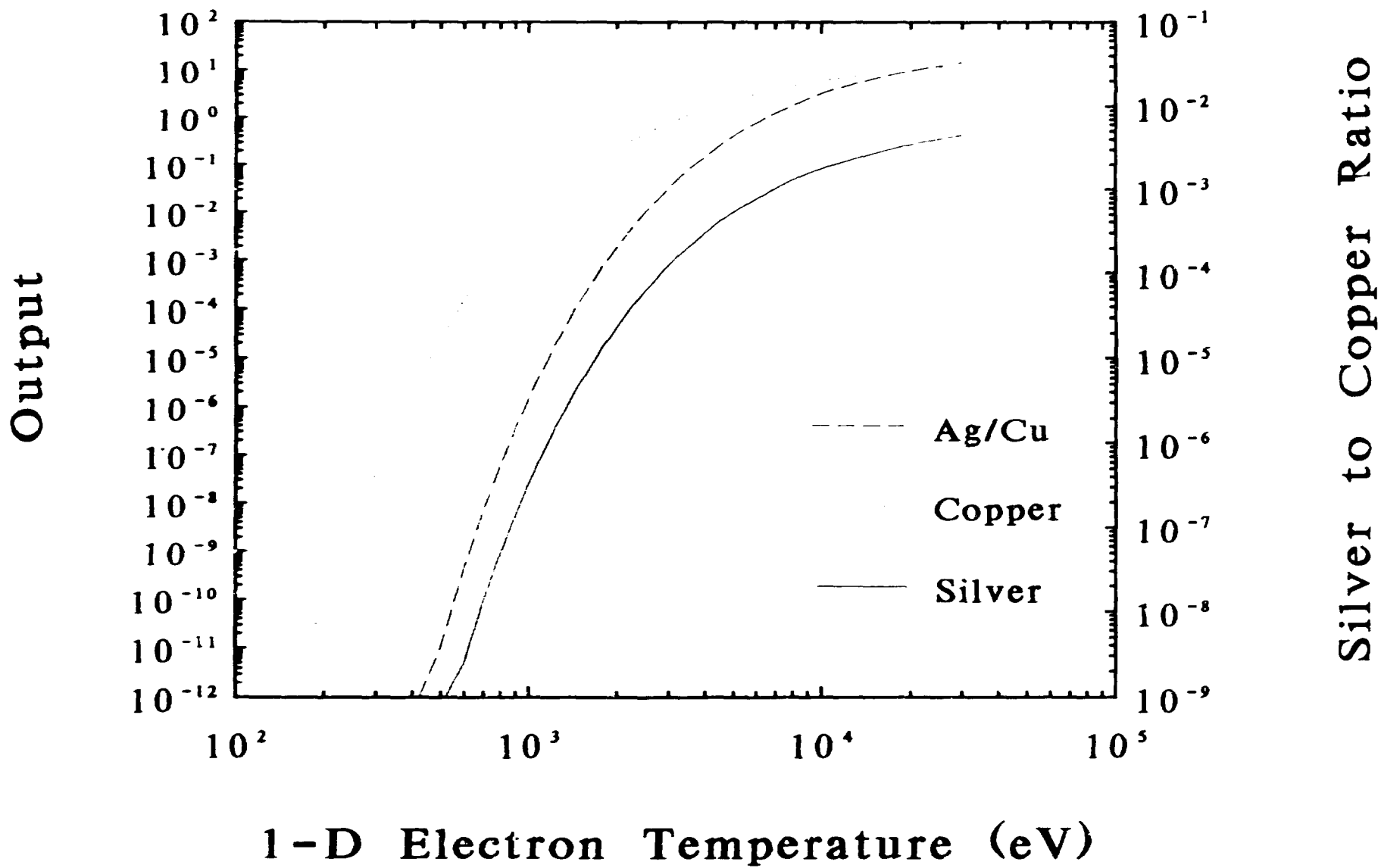
Mat #	Name	Density (g/cm <sup>3</sup> )	Chemical Formula	Klamdas
1	Vyns	1.360	C22H33O2Cl9	0.1E+01
2	Formvar	1.200	C5H2O2	0.1E+01
3	PolyPropylene	0.900	CH2	0.1E+01
4	Mylar	1.380	C10H8O4	0.1E+01
5	Teflon	1.200	CF2	0.1E+01
6	Quartz	2.200	SiO2	0.1E+01
7	Kimfoil	1.210	C16H14O3	0.1E+01
8	Alumina	3.965	Al2O3	0.1E+01
9	Collodion	1.400	C12H11O22N6	0.1E+01
10	Parylene	1.110	C8H8	0.1E+01
11	CelluloseTetr	1.660	C12H16N4O18	0.1E+01
12	Lexan	1.200	C16H14O3	0.1E+01
13	CesiumIodide	4.510	CsI	0.6E-07
14	SiO	2.320	SiO assumed den	0.1E+01
15	PotassiumIodide	3.130	KI	0.2E-07
16	PotassiumBromide	2.750	KBr	0.1E-07
17	LeadIodide	6.160	PbI2	0.2E-08
18	LeadSulfide	7.500	PbS	0.2E-08
19	SilverChlorid	5.560	AgCl	0.3E-08
20	CopperIodide	5.620	CuI	0.2E-07
21		0.000		0.0E+00

Henke {T13,5}Al+{TSiO,.75}+{D14,125}Si

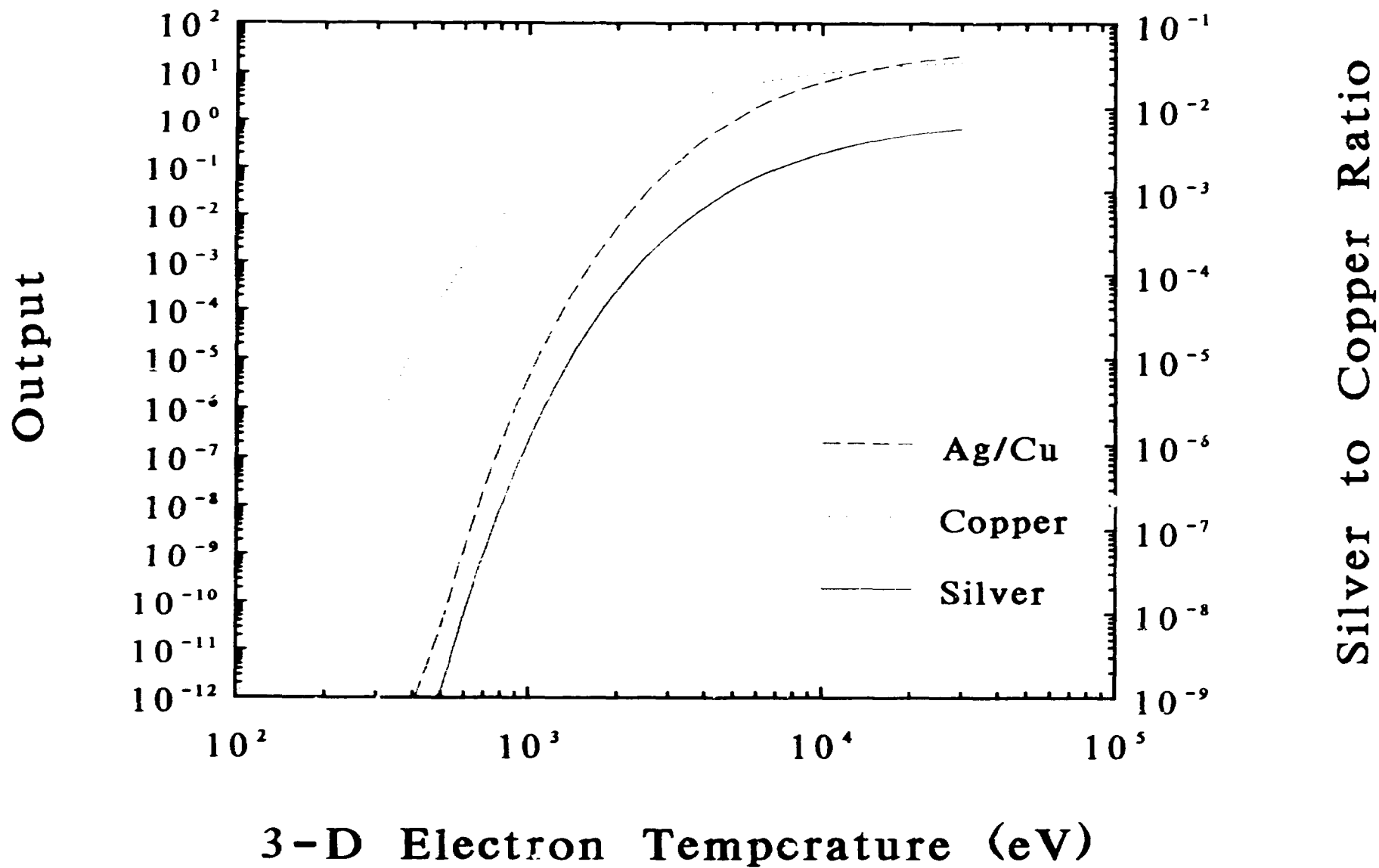


# HOT ELECTRON SIGNAL









Sandia{TPOLY,3000 A}+{T13,250 A}+{CRKI,1000 A}

