Title

Germanium Fet's Point the Way to Lower Noise Preamplifiers

Authors
Elad, Emanuel
Nakamura, Michiyuki

Publication Date
1967-05-01

UCRL-17593
Summary

University of California

Ernest O. Lawrence Radiation Laboratory

GERMANIUM FET's POINT THE WAY
TO LOWER NOISE PREAMPLIFIERS

Emanuel Elad and Michiyuki Nakamura

May 29, 1967

UCRL-17593
Summary

UNIVERSITY OF CALIFORNIA

Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

GERMANIUM FET's POINT THE WAY TO LOWER NOISE PREAMPLIFIERS

Emanuel Elad and Michiyuki Nakamura

May 29, 1967

GERMANIUM FET's POINT THE WAY TO LOWER NOISE PREAMPLIFIERS

Emanuel Elad and Michiyuki Nakamura

Lawrence Radiation Laboratory
University of California
Berkeley, California

May 29, 1967

SUMMARY

A novel low-noise preamplifier for use with semiconductor radiation detectors is described. The preamplifier utilizes the low-noise characteristics of a cooled germanium junction field-effect transistor (JFET).

Preamplifiers based on silicon JFET's are currently used in most high-resolution spectrometers.[1,2] The advantages of the germanium FET over its silicon counterpart are closely related to the properties of the two materials at cryogenic temperatures. Germanium has inherently higher mobility than silicon; lattice scattering in germanium is the dominant scattering mechanism down to liquid helium temperatures, therefore the optimum mobility of germanium is much higher than that of silicon and is attained at much lower temperatures. Also, due to lower ionization energies of impurities in germanium, the density of free carriers in this material at low temperatures is higher than that in silicon. These two factors combine in germanium FET's to give high transconductance (g_m) at very low temperatures.

It is well known that the main noise source of JFET's is the thermal noise of the channel. Thus it could have been expected that

lowering the temperature would result in reduced noise of the device.

The described preamplifier employs germanium FET's operated at 4.2°K to attain their high-gain, low-noise characteristics. The input stage consists of two p-channel JFET's type TIXM12 or TIX301 in cascode. The g_m of these transistors at liquid helium temperature is around 25 000 μmhos, and the input resistance is in the region of 10^{10} to 10^{11} ohm. Input capacitance is approximately 20 pF. The rest of the preamplifier is a conventional type of amplifier using bipolar transistors, which has been described elsewhere.[1]

Pulse-generator resolution of the preamplifier for zero external capacitance is 0.3 keV FWHM (Ge) with a slope of 0.018 keV/pF. The very low sensitivity to external capacitance (detector) is a result of the relatively high input capacitance of the FET's, which, on the other hand, prevents the achievement of higher signal-to-noise ratio.

The preamplifier was used with a low-capacitance silicon detector (at 110°K), and the obtained low-energy spectra of ^{55}Mn and ^{241}Am are shown in Figs. 1 and 2. The K_α and K_β lines of ^{55}Mn, only 0.6 keV apart, are resolved and measured with 0.37 keV resolution. The spectrum of ^{241}Am shows the fine structure of this source; some of the very weak lines (L_η, L_{β_6}, L_{γ_4}) are resolved from the background noise. The L_α line (L_{α_1} = 13.96 keV, L_{α_2} = 13.78 keV) was measured with 0.42 keV resolution, and the L_{γ_1} and L_{γ_6} lines (0.68 keV apart) were resolved. The L_{β_1} and L_{β_2} lines (0.81 keV apart), previously barely resolved,[1] now show a 2:1 peak-to-valley ratio.

We believe that spectra resolutions obtained with the described preamplifier are the best ever published, and can certainly be improved with the technological progress in fabrication of germanium FET's.

Concluding, we can say that the germanium junction FET has proved to be a very-low-noise device when operated at liquid helium temperature. We believe the same is true for other low-energy gap materials, especially the high-mobility materials as InSb, which may serve as the basis for future low-noise devices.

REFERENCES

1. E. Elad, M. Nakamura, "High Resolution Beta- and Gamma-Ray Spectrometer," IEEE, Tran. on NS-14, No. 1, p. 523-532 (February 1967), 13th Nuclear Science Symposium, Boston, Mass., 1966.
2. K. F. Smith, J. E. Cline, "A Low-Noise Charge Sensitive Preamplifier for Semiconductor detectors using Paralleled FET's," IEEE, Tran. on NS-13, No. 3, p. 468-476, (June 1966), Tenth Scintillation and Semiconductor Counter Symposium, Washington, D. C., 1966.

FIGURE CAPTIONS

Fig. 1. Spectrum of ^{55}Mn x rays. Energy in keV.

Fig. 2. Spectrum of ^{241}Am x rays. Energy in keV.

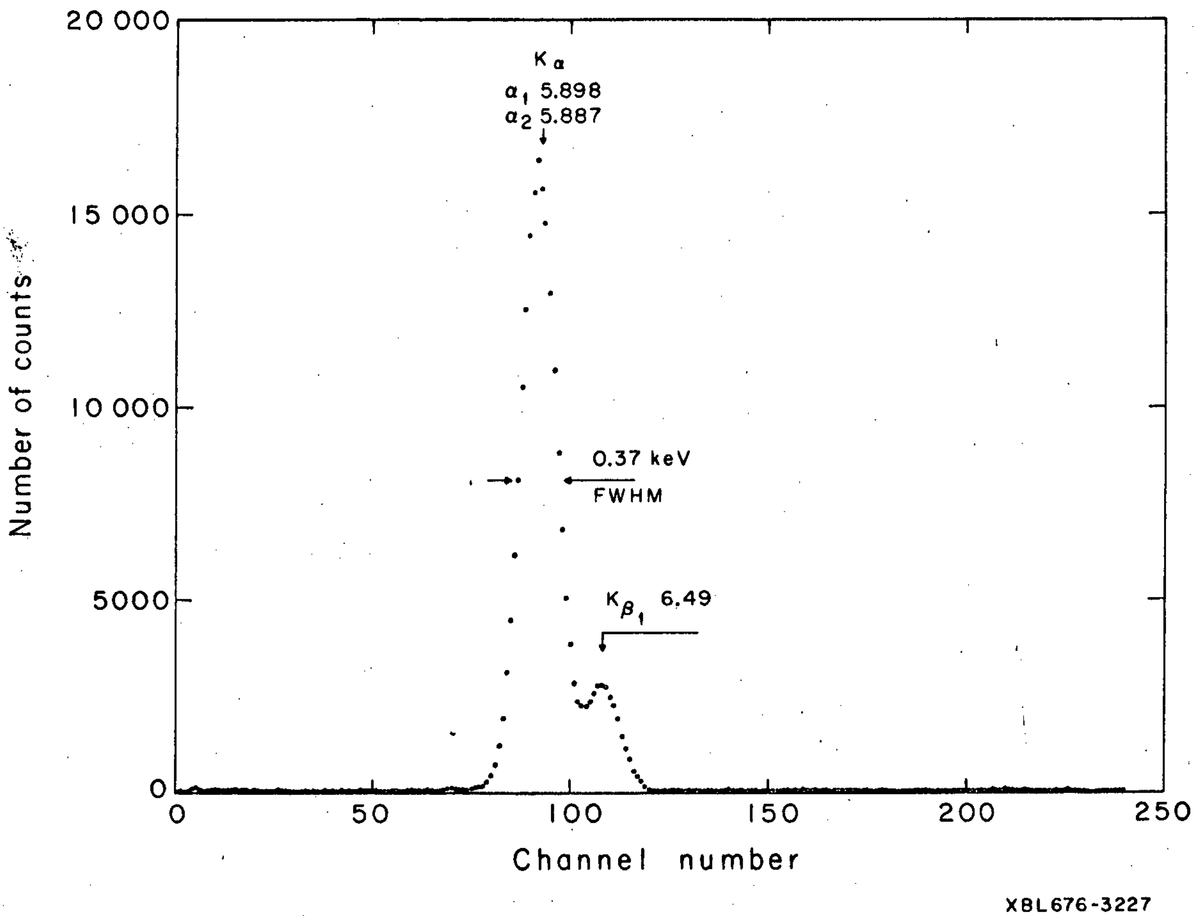
20 000
15 000
10 000
5000
0
Number of counts
K α
α1 5.898
α2 5.887
0.37 keV
FWHM
Kβ1 6.49
0
50
100
150
200
250
Channel number
XBL676-3227

Fig. 1

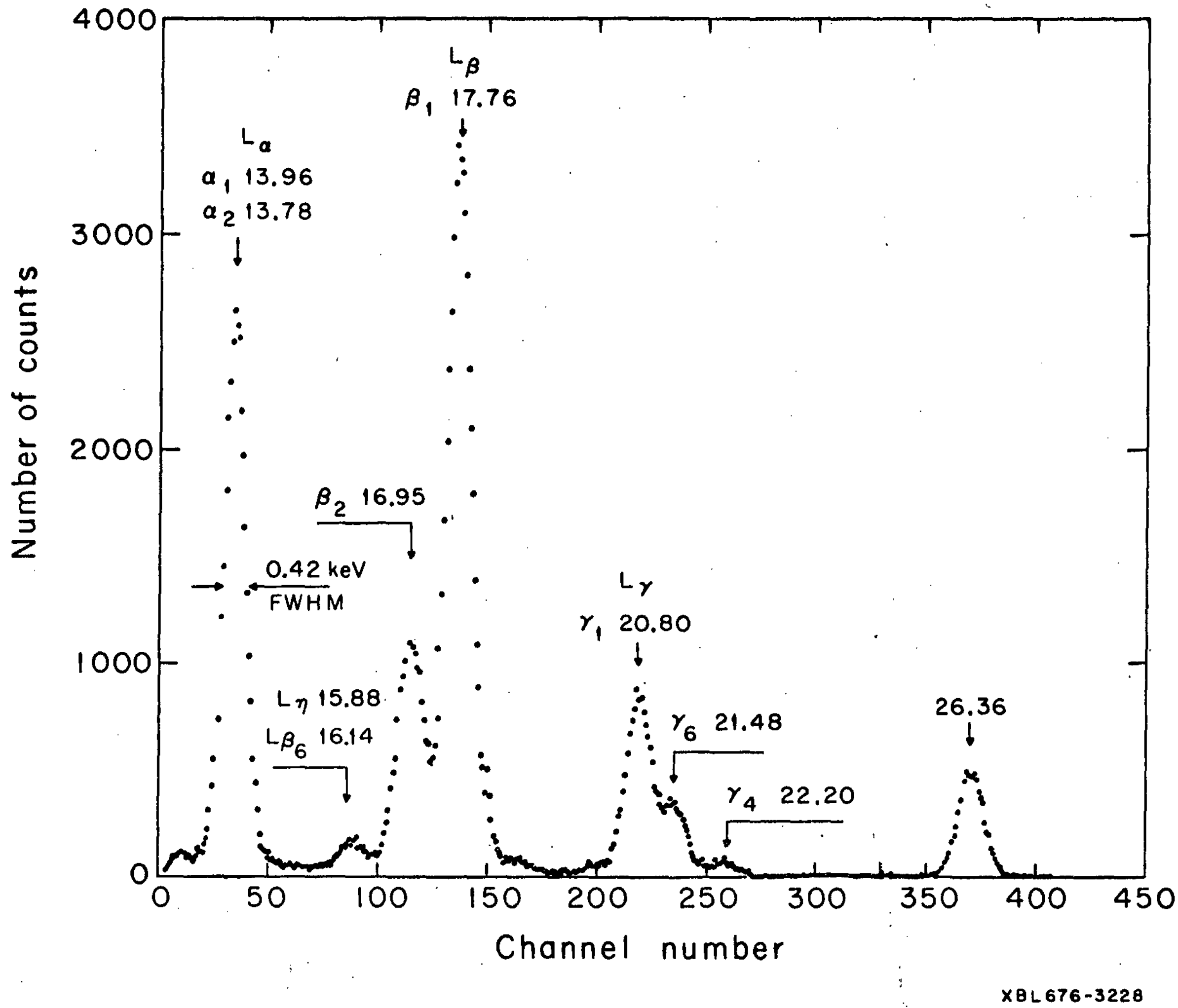
4000
3000
2000
1000
0
Number of counts
L α
α 1 13.96
α 2 13.78
L β
β 1 17.76
β 2 16.95
0.42 keV
FWHM
L η 15.88
L β 6 16.14
L γ
γ 1 20.80
γ 6 21.48
γ 4 22.20
26.36
0 50 100 150 200 250 300 350 400 450
Channel number
XBL676-3228

Fig. 2