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STRUCTURE, PROPERTIES AND RADIATION SENSITIVITY OF ELECTRICALLY BISTABLE MATERIALS

Derek B. Dove, et al

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13. ABSTRACT

This report contains a review of work carried out on the electrical properties of contacts to chalcogenide glasses. The room temperature electrical properties of thin films of glasses have been measured with both sandwich and planar electrode configurations. Conductance and capacitance were measured versus frequency in the two cases as a function of bias voltage. A variation in response was found with bias voltage except in the case of the planar structure with molybdenum electrodes. The variation is quite consistent with a model in which Schottky barriers exist at the electrodes. These results throw serious doubt on previous measurements of conductance and capacitance in thin films where the large changes with frequency observed were interpreted as due to material properties.

Measurements of the spectral distribution of noise currents have also been made for the two film configurations under bias and no bias conditions. All devices showed an increase in noise by several orders of magnitude when a biasing voltage was applied.

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STRUCTURE PROPERTIES AND RADIATION

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Technical Report No. 6

Period Ending 6 February 1973

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ABSTRACT

This report contains a review of work carried out on the electrical properties of contacts to chalcogenide glasses. The room temperature electrical properties of thin films of glasses have been measured with both sandwich and planar electrode configurations. Conductance and capacitance were measured versus frequency in the two cases as a function of bias voltage. A variation in response was found with bias voltage except in the case of the planar structure with molybdenum electrodes. The variation is quite consistent with a model in which Schottky barriers exist at the electrodes. These results throw serious doubt on previous measurements of conductance and capacitance in thin films where the large changes with frequency observed were interpreted as due to material properties.

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EFFECT OF ELECTRODE CONFIGURATION ON MEASUREMENTS ON AMORPHOUS SEMICONDUCTING FILMS

Introduction

Previous work on the electronic properties of amorphous semiconducting films has shown that capacitance and conductance may vary considerably with frequency.[1] These results have been interpreted as due to hopping conduction within the material although some workers have remarked on the possibility of effects occurring due to electrode effects.[2] In the present work measurements on films have been made using two different electrode configurations as shown in Fig. 1.

A sandwich structure is shown in 1a in which electrode glass contact area and also capacitance are maximized. The planar structure of 1b has low contact area and low capacitance.

Preparation

Electrode materials examined were aluminum deposited by thermal evaporation and molybdenum deposited by sputtering. The amorphous semiconducting film was prepared by flash evaporation of bulk $Ge_4Te_{15}As$ or other materials. Electrodes were etched using photoresist techniques and the gap in planar structures was typically of order 10μ. Soda lime microscope slides were used as substrates and a number of devices could be obtained with one glass deposition.

Electrical Measurements

Sandwich Structures

Device conductance and capacitance were measured over the range 50 H_z to 500 k H_z at room temperature using a Wayne Kerr bridge. The results for a

$Ge_4Te_{15}As$ sandwich structure (Al electrodes) are shown in Fig. 2. The variation of impedance with frequency is similar to cases reported by previous workers using sandwich structures.[3] It is of interest that such a variation is also to be expected if there exists appreciable junction capacitance in addition to the bulk capacitance of the structure. Figure 3 shows an effective circuit for a device with appreciable electrode capacitance and Fig. 4 shows the conductance vs. frequency curves calculated for this circuit. It is therefore not necessary to invoke unusual material properties to account for the frequency dependent behavior of such devices. We take the view that properties intrinsic to the glass can only be evaluated after careful consideration and elimination of electrode effects.

The occurrence of electrode capacitance effects could be naturally explained in terms of the formation of Schottky junctions at the electrode glass interfaces. The symmetry of the structure prevents any asymmetry from being apparent in the device i-v curve. However under dc biasing conditions the electrode junction capacitances should vary, leading to a significant change in response with frequency.

The curves of Fig. 5 and Fig. 6 show that there is indeed a large change in both conductance and capacitance with frequency when a dc bias is applied, as much as two orders of magnitude at low frequencies.

To see whether the observed behavior could be qualitatively explained in terms of Schottky junctions at the electrode-glass interfaces, the frequency response of the equivalent circuit shown in Fig. 3 was calculated with the electrode capacitances being taken to vary with biasing potential as expected for Schottky junctions; the effective equivalent circuit being as shown in Fig. 7. The calculated curves of conductance and capacitance versus frequency are shown in Figs. 8 and 9, for comparison with Figs. 5 and 6.

Essentially similar results were obtained with molybdenum electrodes and several other glasses.

The effects noted for sandwich structures are much reduced or are absent in the planar devices. Generally molybdenum electrodes showed less electrode capacitance effect than aluminum contacts. Figures 10 and 11 show conductance and capacitance versus frequency for a planar device with aluminum electrodes. Some variation with dc bias current can be noted. Figures 12 and 13 show curves for a device with molybdenum planar electrodes, in this case virtually no variation with bias current is to be seen.

The striking difference between these curves and those obtained with sandwich structures reinforces the conclusion that electrode properties cannot be neglected in measurements on amorphous semiconductors, and that some of the results on thin films by previous workers have been dominated by electrode capacitance effects.

Discussion of Results

The absence of appreciable changes in ac impedance with dc bias in the case of planar structures (particularly with molybdenum electrodes) indicates that the planar configuration may be much more reliable than the sandwich structure for electron transport measurements.

If it is accepted that the conductance and capacitance measured with planar geometry electrodes are characteristic of the amorphous semiconductor rather than the electrodes, then in most cases there is no evidence for hopping conduction at the low frequencies involved in the present measurements. In one case an ac conductance versus frequency curve was found however to follow a frequency to the 0.8 power very closely, Fig. 14, suggestive of hopping conduction with a random distribution hopping centers as predicted by Austin and Mott.[4] Measurements made with sandwich electrodes on the same material did not give a linear plot and various frequency dependences could be obtained depending on the frequency range of the measurement. The conclusion cannot be too strongly drawn, that electrode effects must be properly taken into consideration or eliminated before ascribing anomalous impedence versus frequency measurements to intrinsic material properties. In the present work a planar structure with molybdenum electrodes was found to be suitable for measurements on $Ge_4Te_{15}As$ and similar glasses. A test for electrode junction capacitance consists of repeating impedence versus frequency measurements under dc bias conditions, with of course proper care that there is not interference between biasing circuit and a.c. measuring bridge.

NOISE MEASUREMENTS

Measurements of the spectral distribution of noise current for sandwich and planar electrodes were carried out with a multichannel spectral analyzer. At zero bias, essentially thermal noise was observed. The variation of equivalent noise current with frequency is shown in Fig. 15 for a sandwich structure having aluminum electrodes and $Ge_4Te_{15}As$ glass. The rise at higher frequencies is due to the increasing conductance with frequency exhibited by this kind of structure.

Figure 16 shows the noise spectrum with an applied bias current of 3.0μa, normalized to the equivalent dc noise current. It can be seen that there is an increase in noise output by 6 orders of magnitude at low frequencies. Such a large change is consistent with the conclusion that blocking electrodes are formed on the sandwich structures.

Noise measurements on planar devices show similar but less pronounced results, Fig. 17, indicating that Schottky junctions also probably exist in the planar structures but that the capacitance and conductance so introduced are negligible in this case during the bridge measurements.

Conclusions

Electrode effects play a major part in determining the variation of capacitance and conductance versus frequency of sandwich structures formed with amorphous semiconductors. The interpretation of measured curves in terms of a simple equivalent circuit throws considerable doubt on the interpretation of such curves by previous workers, in terms of electron hopping conduction in the material. The very good qualitative agreement between observed and predicted behavior of devices under dc bias conditions reinforces this conclusion. A planar electrode structure was found to be satisfactory for the measurement of electron transport properties, and hopping conduction was not observed in some films that showed a considerable change in impedence when measured in the sandwich configuration.

Essentially thermal resistance noise was found in devices measured under zero bias conditions. The equivalent noise current however increased by many orders of magnitude upon application of a bias current.

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(2) H. Fritzsche, J. of Non-Cryst. Solids, 6, 49 (1971).
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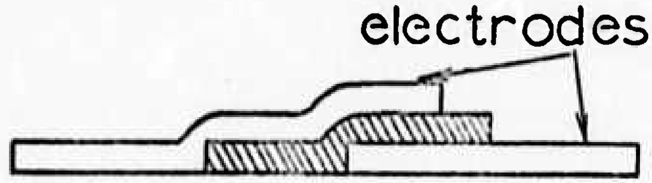
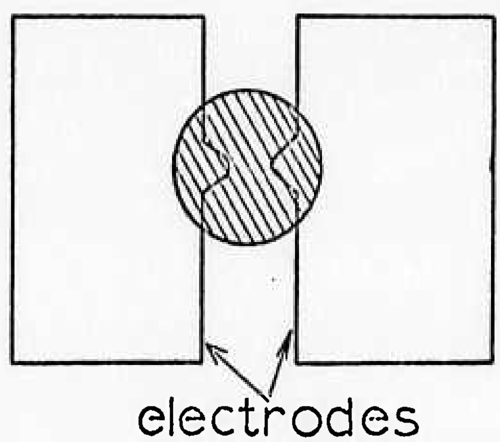
(4) J. G. Austin and N. F. Mott, Advan. Phys., 18, 41 (1969).



(a)



(b)

Figure 1. (a) Cross section of sandwich structure.
(b) Plan view of planar structure.

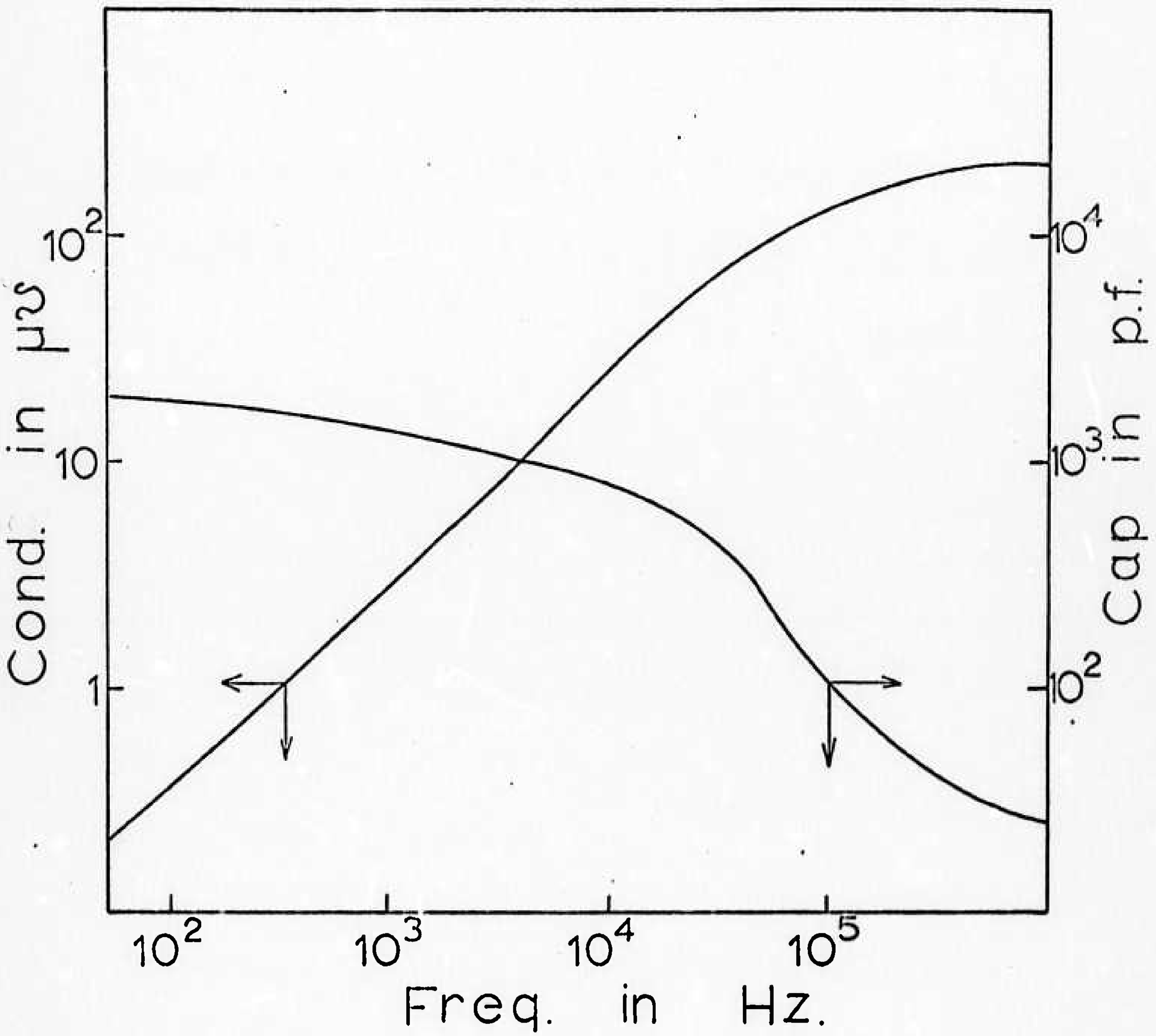


Figure 2. Conductance and capacitance measured versus frequency for a sandwich structure with Al electrodes and $Ge_4Te_{15}As$ glass.

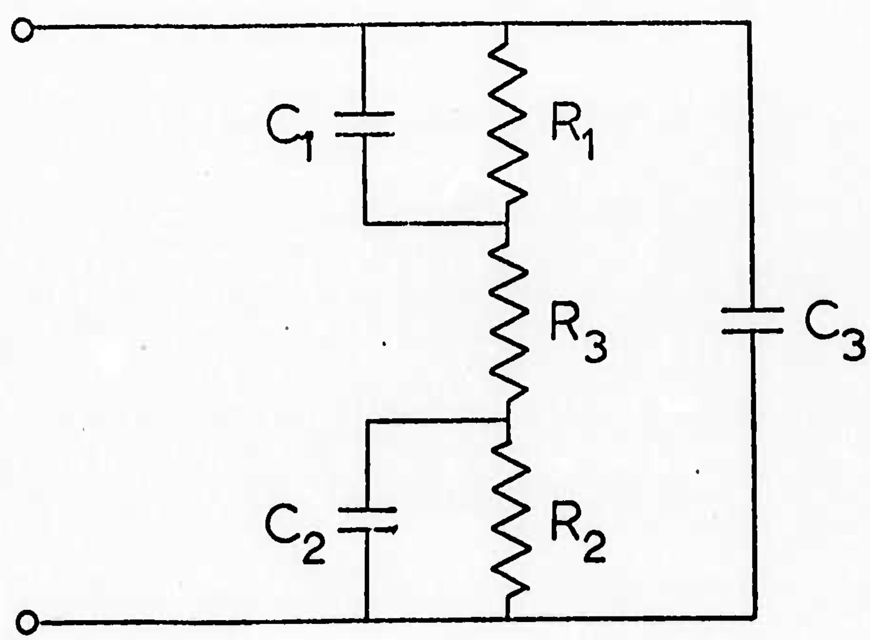


Figure 3. Equivalent circuit for glass with electrode capacitances C_1 and C_2.

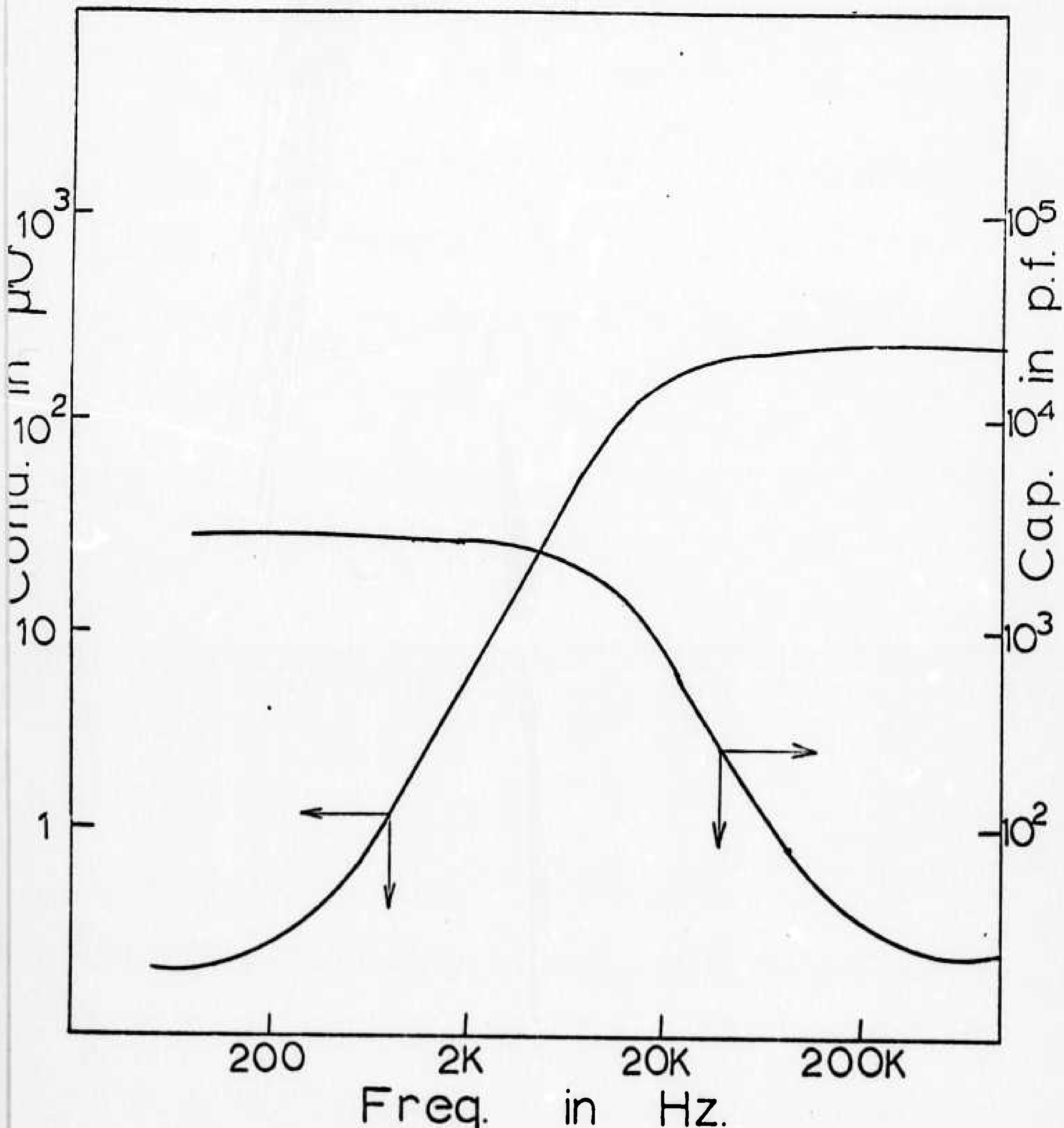


Figure 4. Calculated conductance and capacitance versus frequency for the equivalent circuit of Fig. 3. (With $C_1 = C_2 = 5.2 \times 10^{-9}$F, $C_3 = 2.7 \times 10^{-11}$ F, $R_1 = R_2 = 2.5$ MΩ, $R_3 = 4.7$ KΩ.)

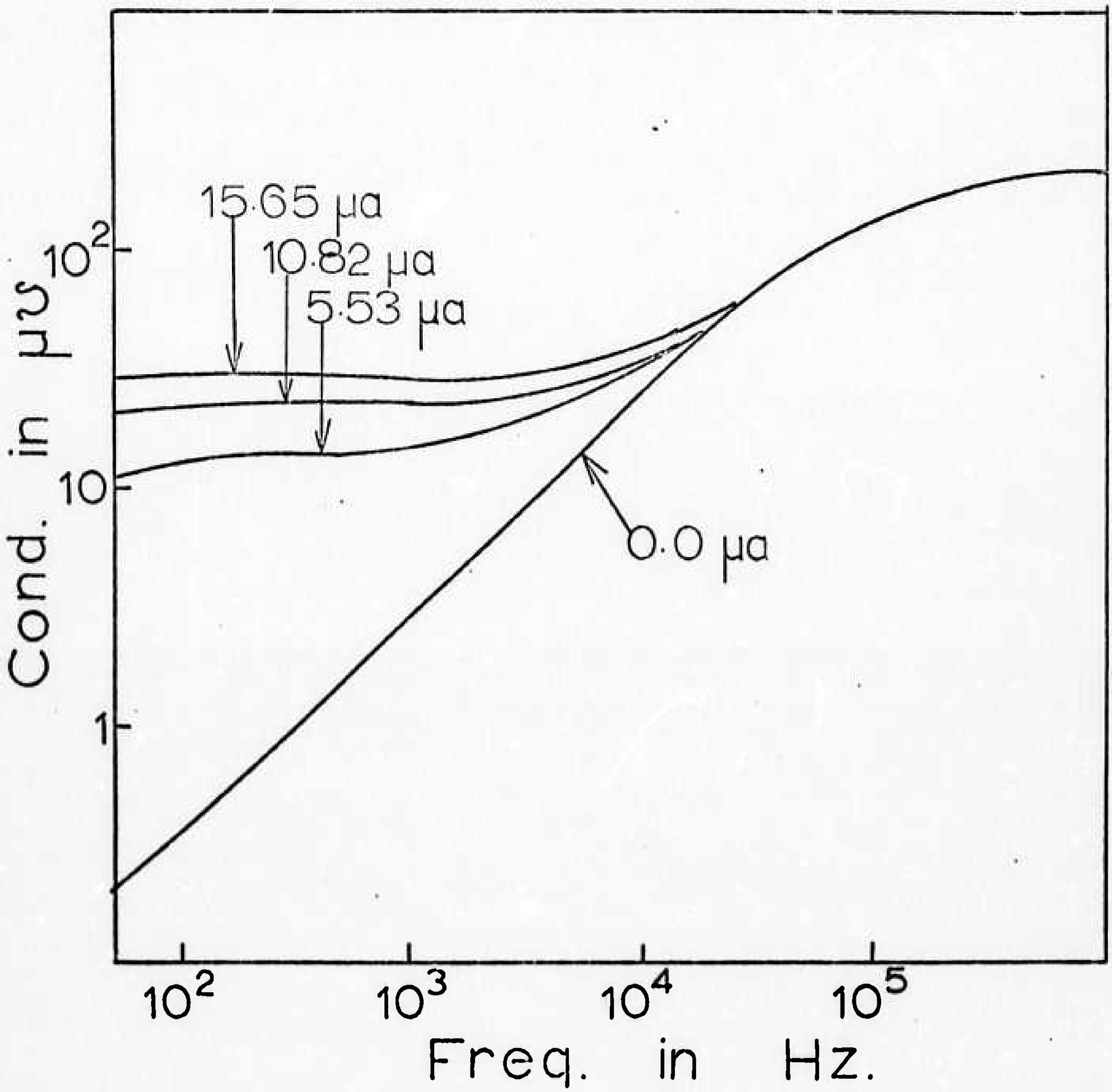


Figure 5. Conductance versus frequency for an Al electrode, $Ge_4Te_{15}As$ sandwich, structure held at different constant bias current values.

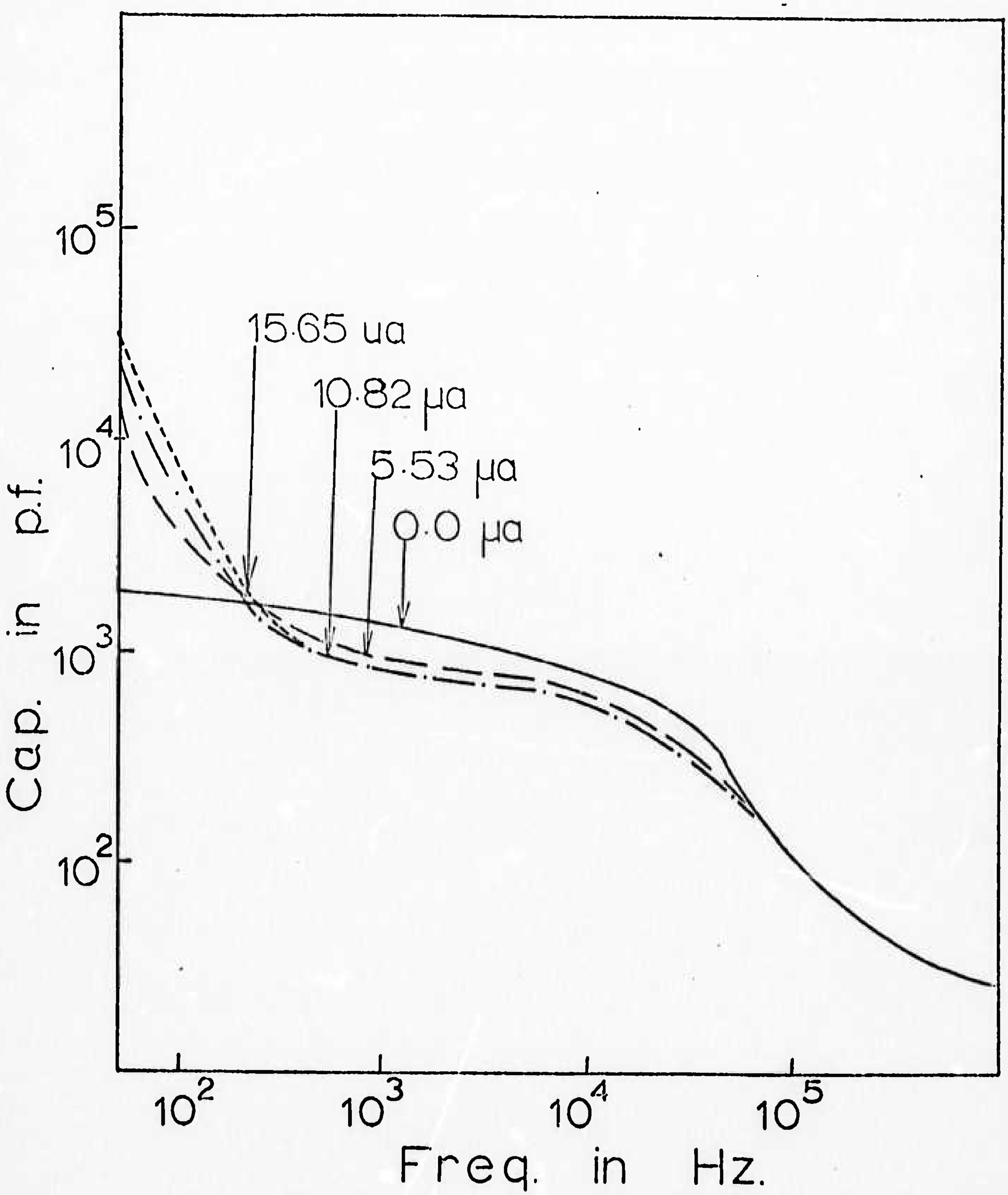


Figure 6. Capacitance versus frequency for an Al electrode $Ge_4Te_{15}As$ glass sandwich structure held at different constant bias currents.

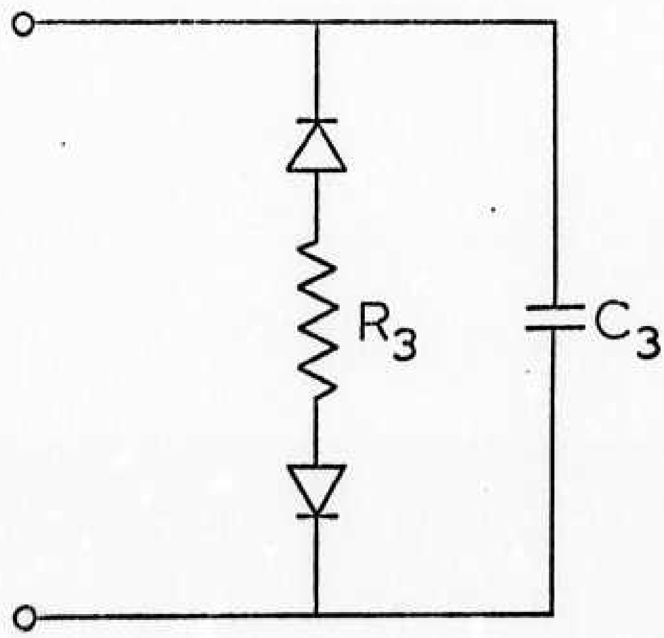


Figure 7. Equivalent circuit of glass with blocking electrodes.

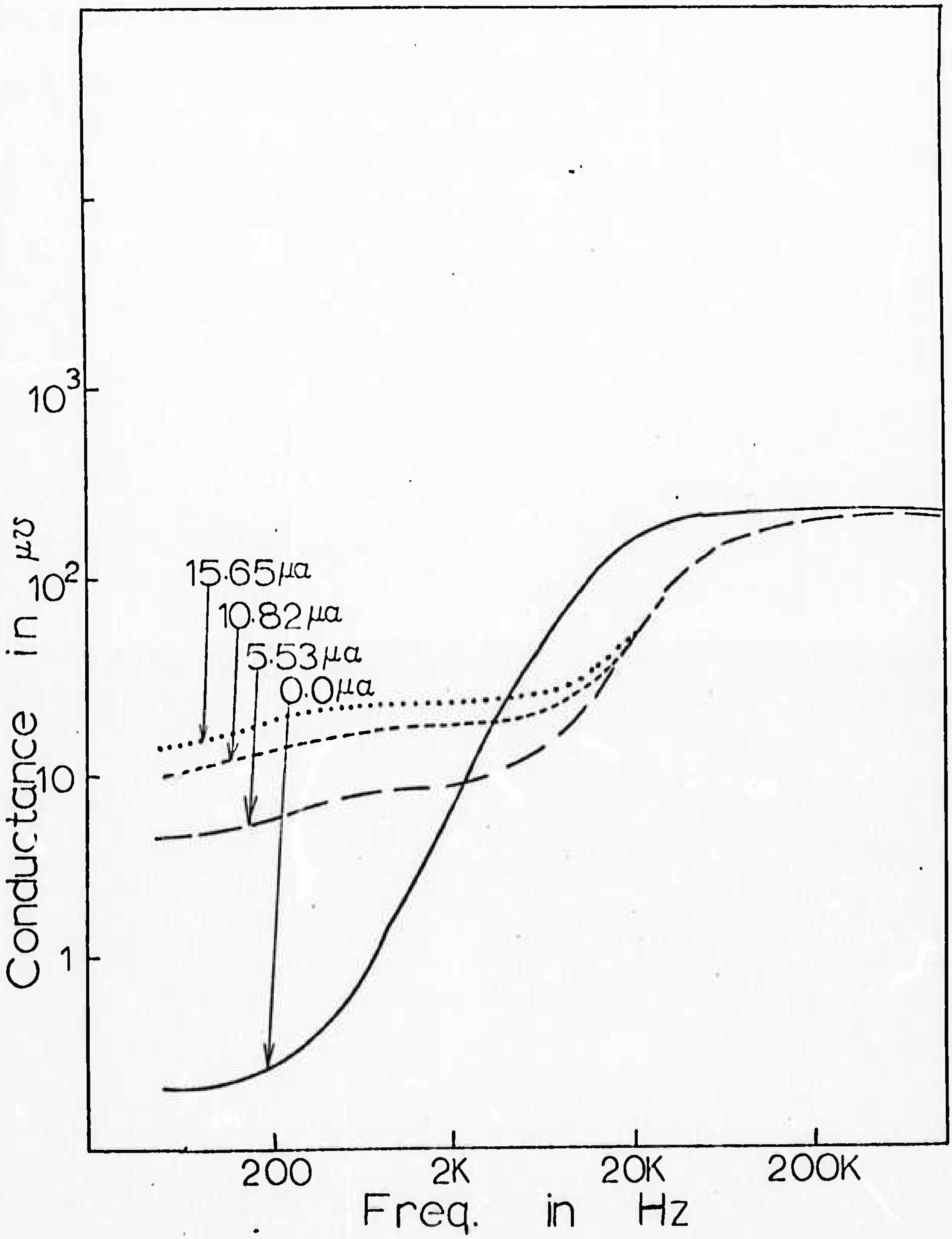


Figure 8. Conductance versus frequency calculated for the equivalent circuit of Fig. 3 where the circuit values have been adjusted to correspond to Fig. 7 under bias conditions. $C_2 = 3 \times 10^{-9}$ F, $C_2 = 8 \times 10^{-10}$ F, $C_3 = 2.6 \times 10^{-11}$ F, $R_1 = R_2 = 52.0\text{k}\Omega$, $R_3 = 5.2$ kΩ.

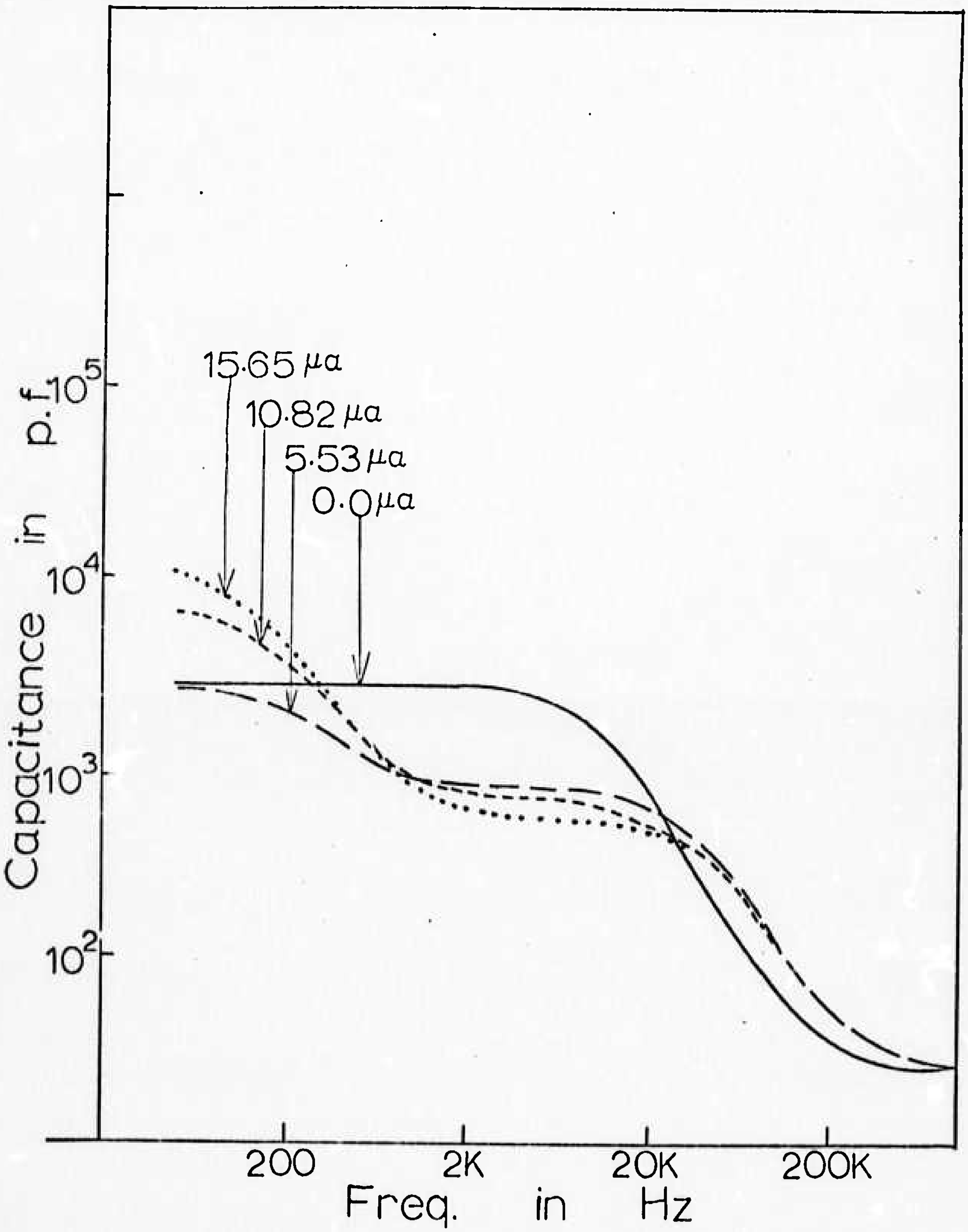


Figure 9. Capacitance versus frequency calculated for the conditions of Fig. 8.

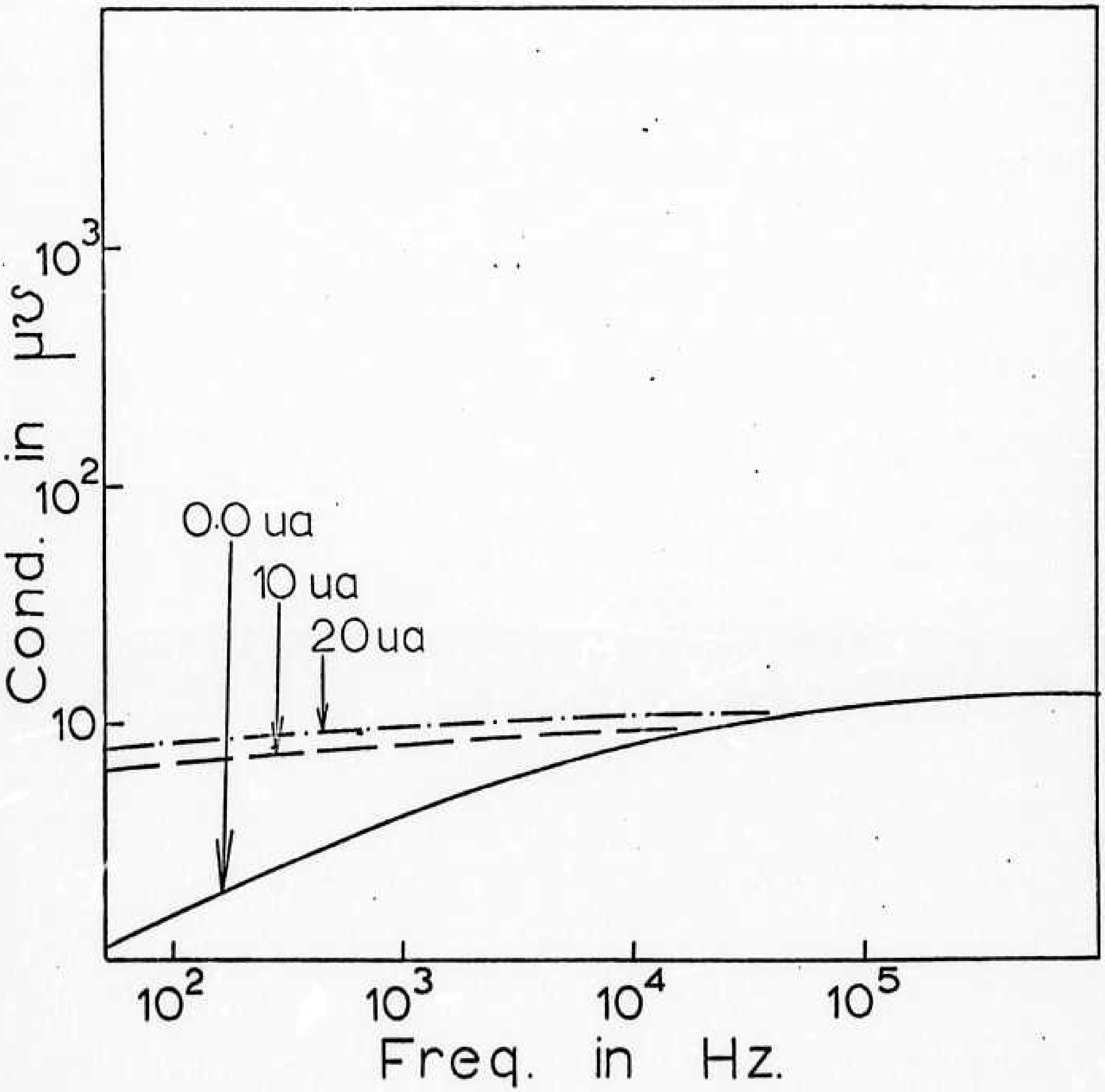


Figure 10. Measured conductance versus frequency for a planar structure with Al electrodes and $Ge_4Te_{15}As$ glass.

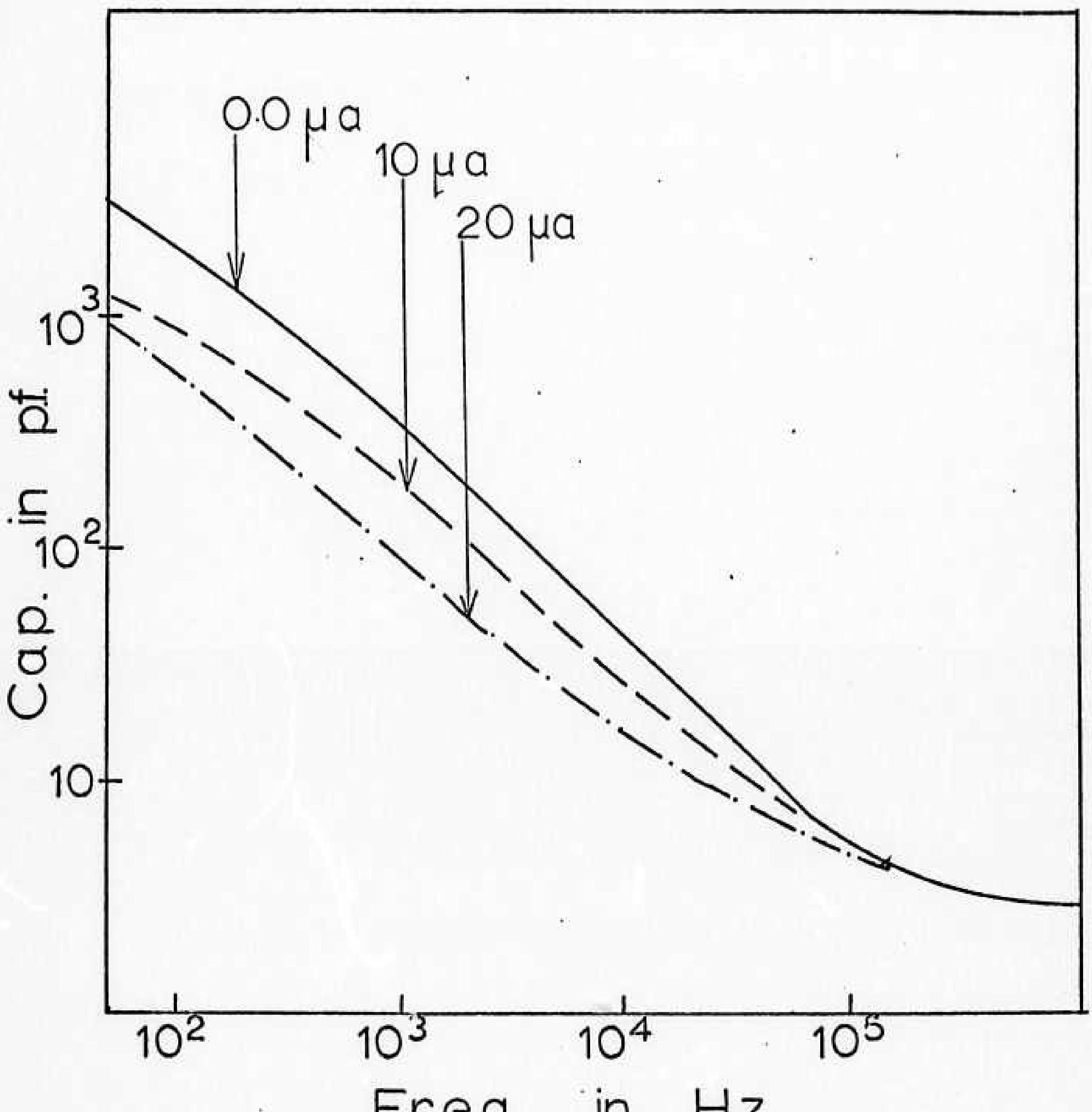


Figure 11. Measured capacitance versus frequency for a planar structure with Al electrodes and $Ge_4Te_{15}As$ glass.

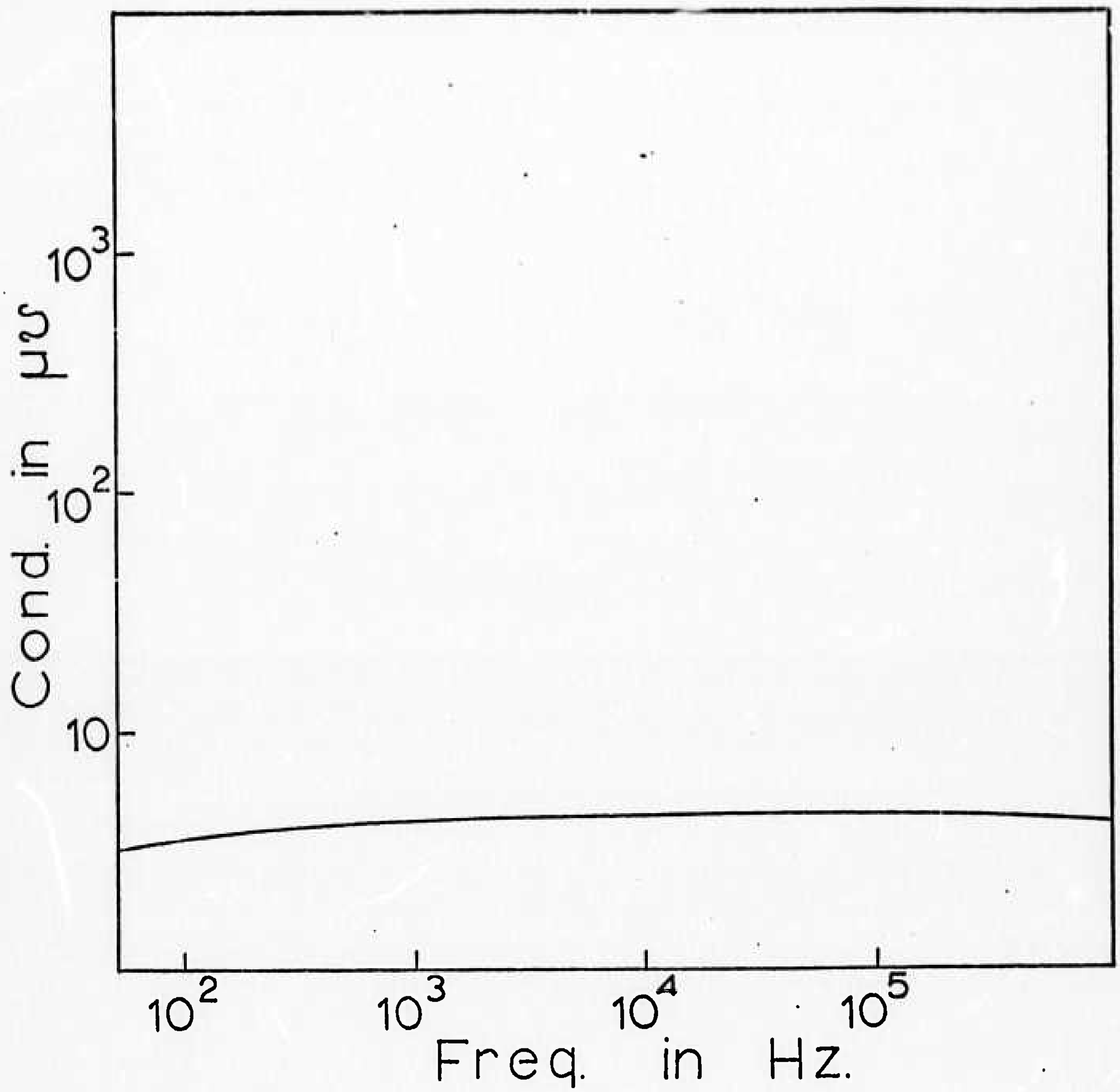


Figure 12. Measured conductance versus frequency for a planar structure with Mo electrodes and $Ge_4Te_{15}As$ glass. The curve is essentially unchanged by application of a bias field.

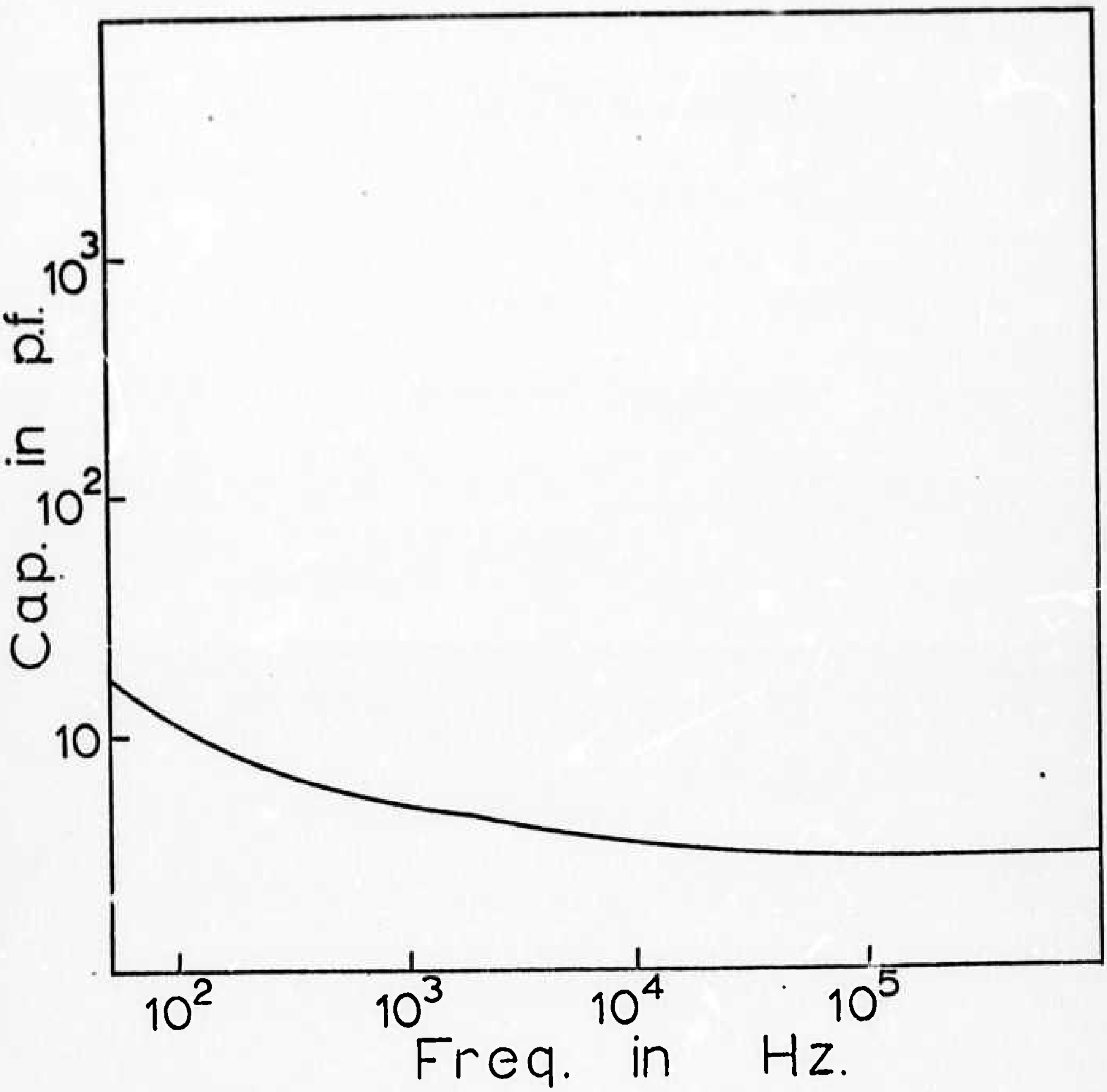


Figure 13. Measured capacitance versus frequency for a planar structure with Mo electrodes and $Ge_4Te_{15}As$ glass. The curve is essentially unchanged by application of a bias field.

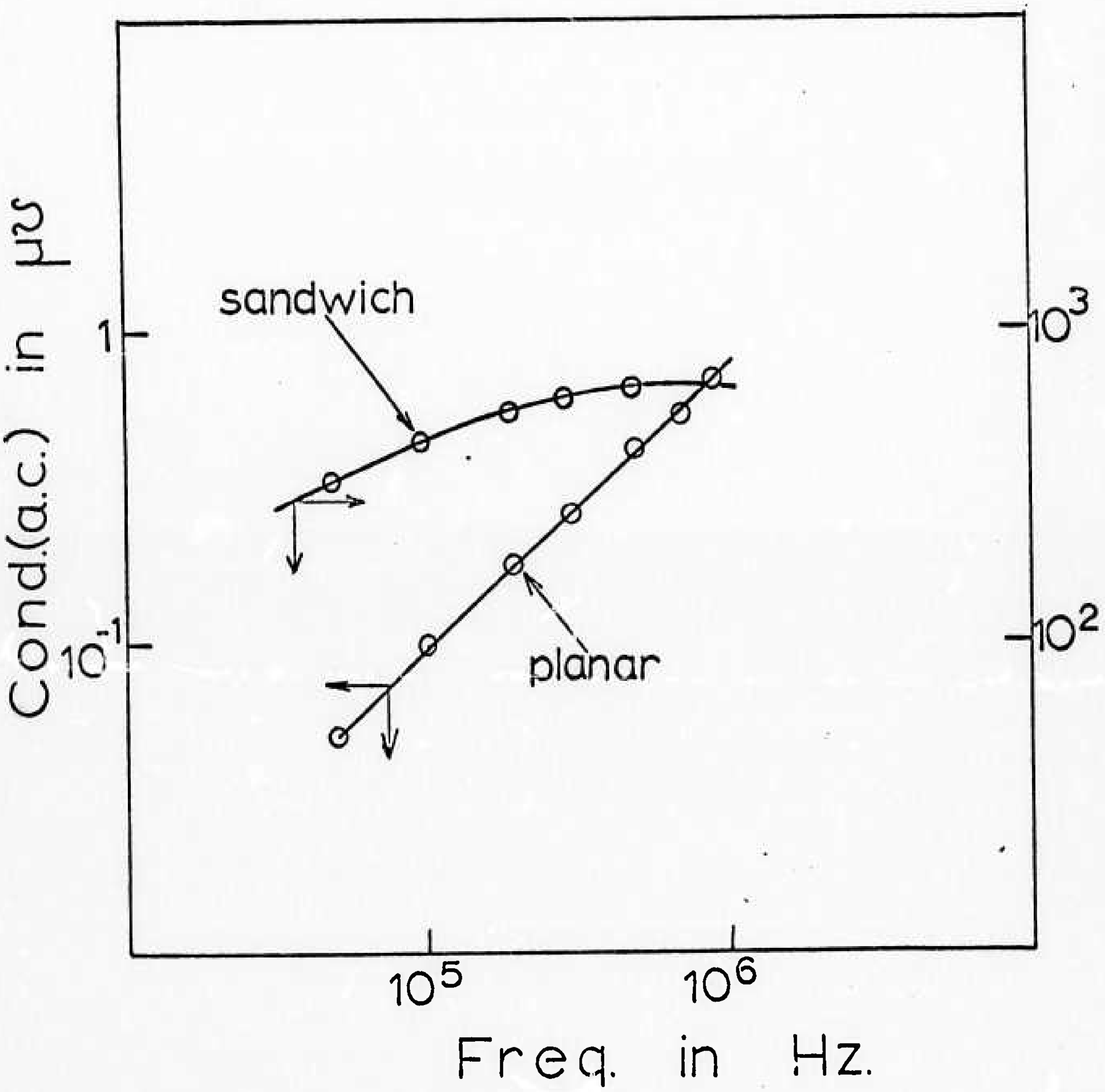


Figure 14. Plot of ln (a.c. conductivity) versus ln (frequency) for $Ge_2Te_{16}As$ glass with Mo electrodes. The curves show the different results obtained with planar and sandwich electrodes.

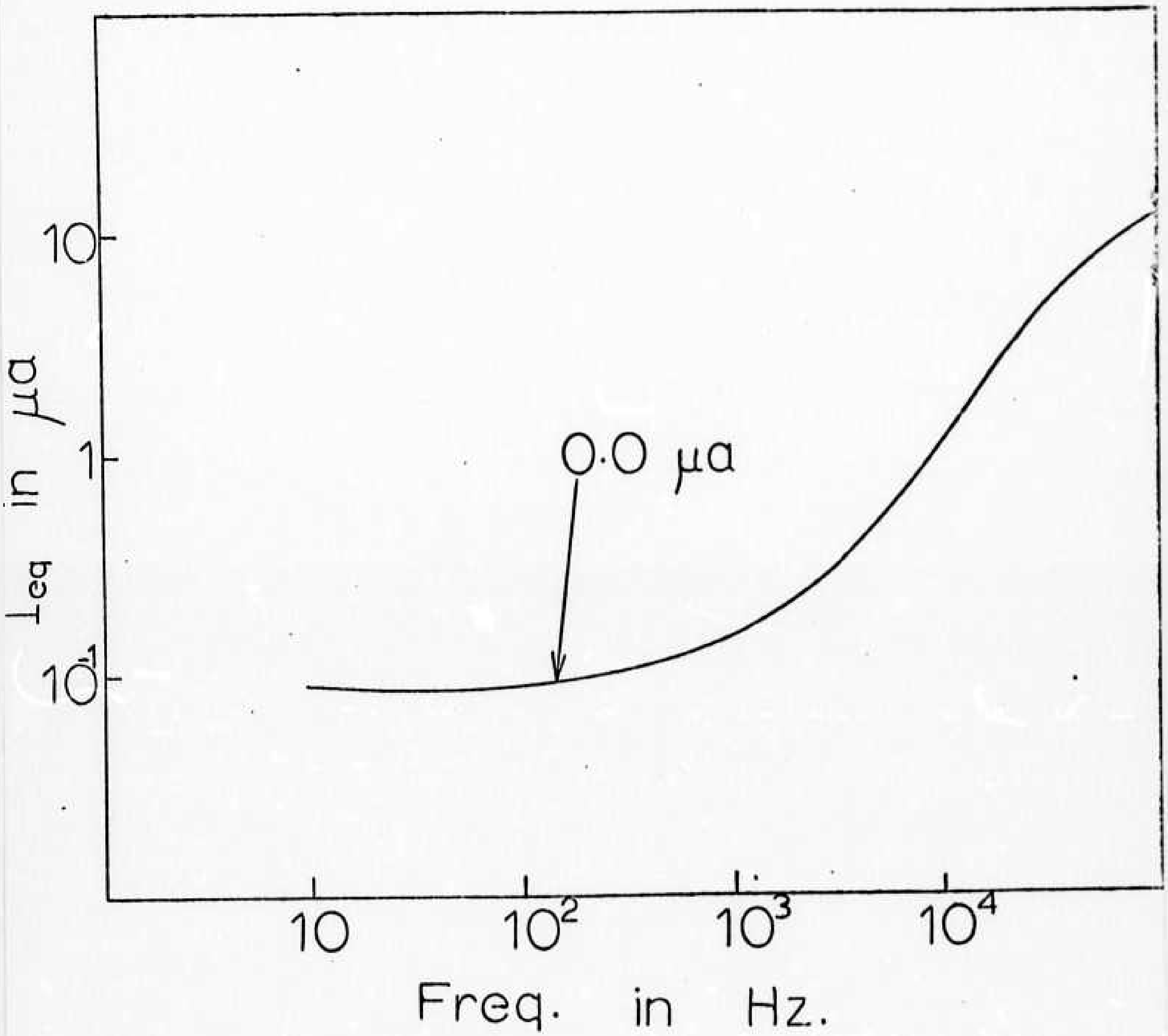


Figure 15. Equivalent noise current of an Al electrode, $Ge_4Te_{15}As$ sandwich structure under zero bias. The increase at higher frequencies is due to the increase in conductance with frequency exhibited by these devices.

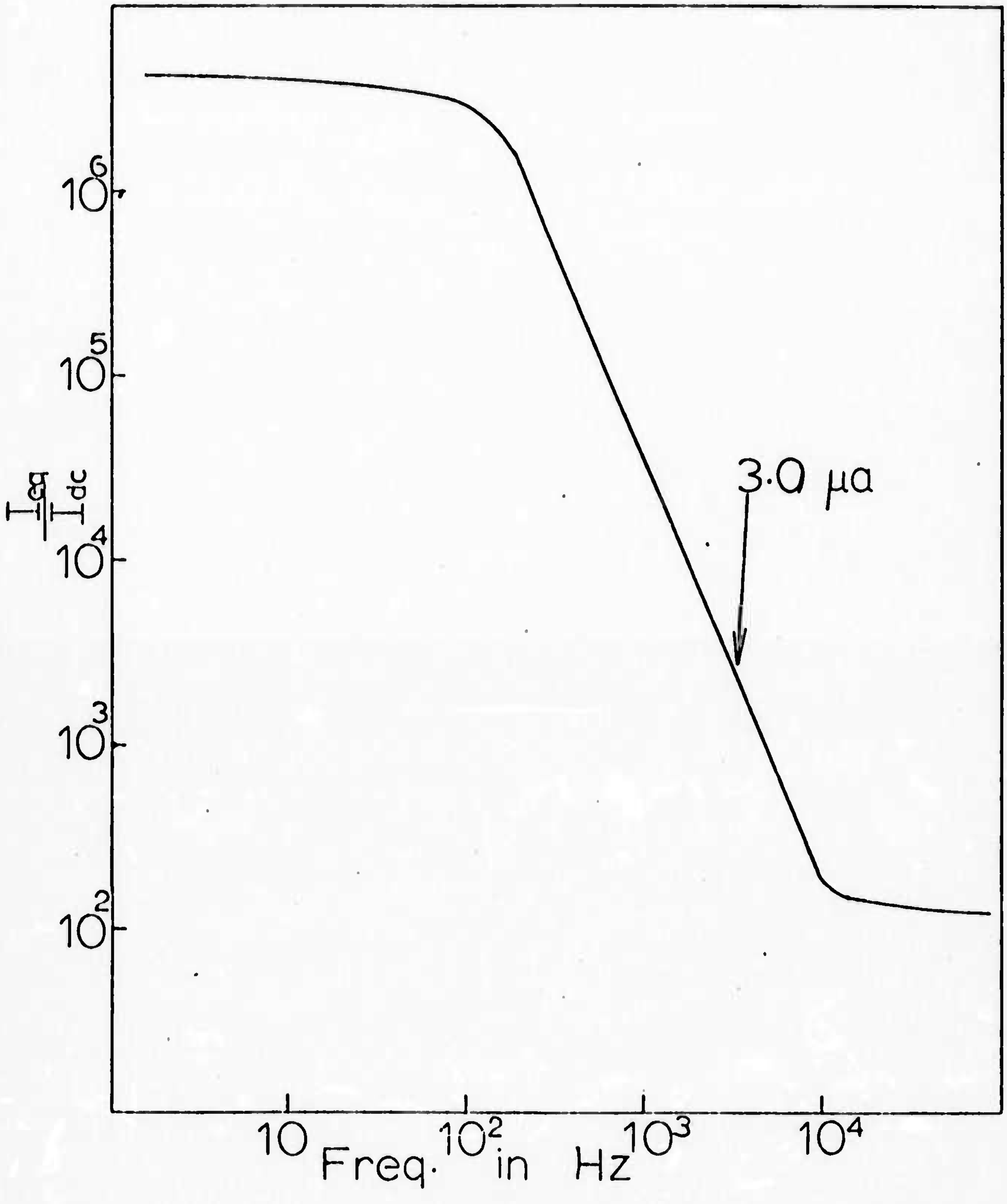


Figure 16. Ratio of equivalent noise currents of device of Fig. 15 under 3.0μA bias condition.

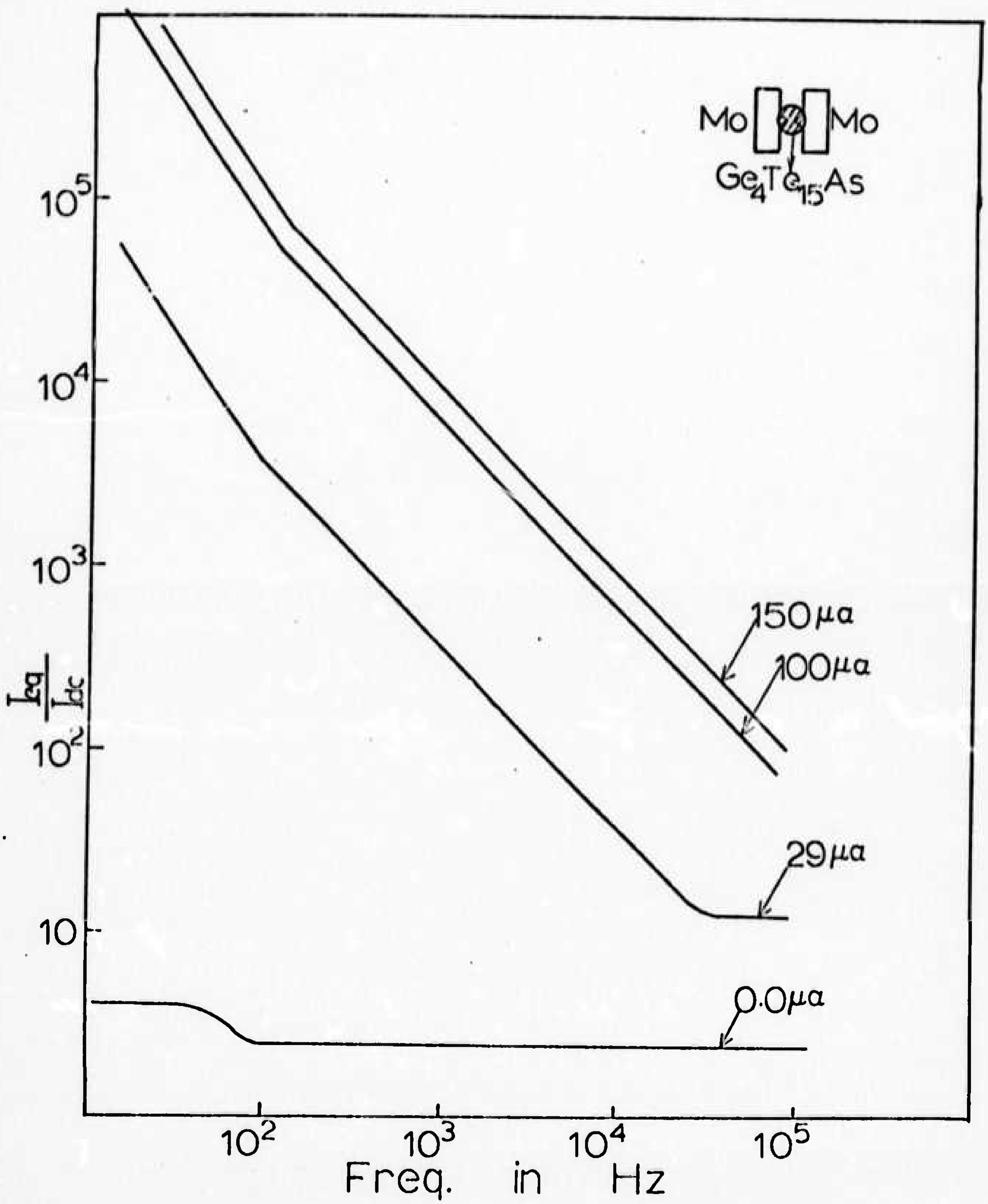


Figure 17. Ratio of equivalent noise currents for a Mo electrode, $Ge_4Te_{15}As$ glass planar structure, as a function of frequency.