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WIRE CHAMBER AGING AND WIRE MATERIAL

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Abstract

Recent studies on wire chamber aging has shown surprising results ^{1,2} indicating that anode wire material may have a strong influence on the useful life-time of a chamber or counter. The aging process discussed here is related to changes in the surface characteristics of the anode wires. Those changes may be due to an oxidation process involving molecules produced from the dissociation of organic quenching agents during the avalanche process. It is observed that after some running time the anode wire surface is coated with a nonconductive film, which drops the electric field around the anode wire, reducing the gain as the aging process continues.

Aging due to polymerization and other processes have been known since the early years of Geiger and proportional counter operation. Interesting phenomena found here shows that the aging

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process is not only dependent on the gas mixture, it is strongly related to the anode material. Results reported earlier¹ showed that chambers with gold plated tungsten anode wire using Argon-Ethane-Ethyl alcohol gas mixtures performed well for a very long time. They showed no appreciable loss of gain after an accumulated charge of one to two Coulombs per centimeter of wire length. There was no evidence of polymerization.

Aging was accelerated when the gold plated tungsten anode wire was replaced by Stablohm-800 resistive alloy (75% Ni + 20% Cr + Al + Cu) wire using the same gas in the same chamber. However, the gas mixture of Argon-ethane-isopropyl alcohol provides a very long lifetime for a drift chamber made of Stablohm-800 anode wire. The details of the findings are discussed below.

Resistive Alloy as Anode Wire

A small chamber (Figure 1) was used for this test. The anode wires were Stablohm-800 resistive wire (50 μm diameter), the field shaping wires were 150 μm stainless steel and the cathode planes were 25 μm thick aluminum strips on 100 μm thick of G-10 sheets. The purpose of these choices was to use all the materials in the same configuration as in the radial wire drift

chambers³ of the CDF. The resistive wire is used for determining track coordinates along the wire by current division.

Equal portions of argon and ethane gas were bubbled through ethyl alcohol at -7° C, adding 1.1% vapor in solution. Using an intense Sr^{90} β -source (collimated to illuminate 6mm) the wire current drawn from the HV-power supply was monitored for the following tests. The count rate obtained from the wire approached 2×10^5 per second and showed a $0.4 \mu\text{A}$ current draw. A pulse height spectrum of Fe^{55} was taken by illuminating various parts of the chamber. The spectrum obtained at the illuminated spot was compared to the spectra obtained from the adjacent wire for 5.9 keV peak as far as 6 cm away from the spot. Wire aging appeared after the first day of running time. Figure 2 shows the drop in the pulse height as a function of the accumulated charge. Aging is reflected in the pulse height resolution as seen in Figure 3. The results were alarming since earlier tests showed argon-ethane gas needed ethanol as an additive quenching agent to prevent breakdowns, glow discharges and fast aging.

50% Ar/50% C_2H_6 gas mixture has been popular due to its excellent drift velocity saturation. It provides good spatial resolutions at atmospheric pressures. The test results obtained earlier with argon-ethane-ethanol using gold plated tungsten wires showed very little or no aging up to 1-2 Coulomb charge,¹ per wire per cm^2 . The difference is related to the

material of the anode wire. We needed a remedy and this remedy was replacing ethanol vapor with isopropyl alcohol vapor.

Test with Argon-Ethane-Isopropyl Alcohol Gas Mixture Using
Stablohm-800 Wire

Using the same chamber with the Ni-Cr-Al-Cu alloyed wires, the above tests were carried out under the identical conditions after replacing ethyl alcohol with isopropyl alcohol. The temperature of the alcohol bath was -5° C, adding 0.25% vapor to the 50% A/50% C_2H_6 gas mixture. This gas mixture resulted in about a factor of 50 longer life-time for the same amount of gain drop. The gain drop was 4% after an accumulated charge of 0.6 Coulomb. Figure 4(a) shows the pulse height spectra at the beginning of the runs and after accumulating 0.6 Coulomb charge per cm^2 per wire. Pulse height resolution is unaffected.

The same gas mixture using 50 μ m gold plated tungsten wire showed no aging up to 2 Coulomb per centimeter of wire length. There was no gain drop, no change in pulse height resolution. No residue could be seen on the exposed region of the wire. The test was stopped to carry out the following experiments. Figure 4(b) shows the pulse height spectra obtained with the Fe^{55} source on the aged spot.

Stablohm Wire with A-C₂H₆-CH₃OH

To gather more clues on the aging process of the resistive alloy, a 50% A/50% C₂H₆ gas mixture was bubbled through methanol at -5° C, adding about 2% vapor to the mixture. The wire aged very rapidly. After four hours of running with 0.4 μA average current, (corresponding to 0.008 Coulomb per centimeter) wire pulse height resolution was destroyed and average pulse height dropped (Figure 5). The aging was faster with methanol than ethanol mixture possibly due to higher concentration of alcohol (2% methanol) mixing. We will see further that the dissociation products of ethanol and methanol may be responsible for this aging. We also see a peak appearing below 5.9 KeV peak; this will be explained further in the paper. Ethanol and methanol vapors are effective in preventing polymerization, but the dissociation products of these are reacting with this particular wire. Two remaining questions are: which components of the Stablohm wire are sensitive to dissociation products of the ethanol and methanol, and why aren't they reacting with the dissociation products of isopropanol. To answer the first question, the following aging tests were done on aluminum, nickel, copper, and chrome.

Tests with Aluminum Wire:

Hard aluminum (Al 5056) showed very fast aging with argon-ethane-methanol mixture. A double 5.9 keV peak appeared after 0.001 C/cm² on the 6 mm portion of the wire. The height of the lower peak was increased after 0.003 C charge as seen in Figure 6. One possible explanation for the double peaks is that the aged spot is coated with fairly uniform layers of Al₂O₃ which is highly resistive. The resistive layer may charge up, and polarize under the electric field; thus reducing the gas gain in that region. The lower peak is from the aged region. The scattered X-rays from the collimator result in the higher peak. Further results given will help resolve this issue. A remarkable point is that both peaks show good resolutions indicating a uniform aging of the anode wire. The color of the aged surface of the wire was like white chalk.

Nickel Wire:

Nickel wire also aged but not as fast as the aluminum wire did. There was a 16% gain drop after 0.05 C charge per cm² per wire with the argon-ethane-methanol mixture. Figure 7 shows again a lower peak appearing on the shoulder of the 5.9 keV peak. The surface of the aged spot had red and blue colors, depending on the intensity of the aging, indicating surface oxidation .

NiO is an insulator³ but not as good an insulator as Al₂O₃. Aged surfaces of Ni and Al wires were examined using α -scattering by Dr. S. Majewski (University of Florida). The spectral analysis showed a measurable amount of oxygen on both surfaces.

Neither with nickel nor with aluminum was any substantial residue seen on the aged sections of the wires. Scanning electron microscope pictures were taken at Argonne National Laboratory by B. Tani. Figures 8(a) and (b) show these pictures on the clean and aged parts of the aluminum and nickel wires respectively. There is no visible increase in the wire thickness but there may be some evidence of corrosion on both wires. X-ray analysis was taken during the scanning process of the aluminum and nickel wires. Figures 9(a) and (b) show that there are no detectable elements above aluminum mass like Si and Br which have been found in the polymerization processes. Only the expected impurities in the nickel or aluminum were detectable.

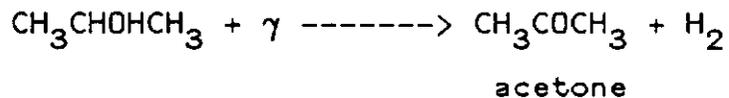
Copper, Stainless Steel, and Platinum:

These three wires showed no measureable aging after 0.15 C/cm² per wire using the argon-ethane-methanol gas mixture. Because gold, platinum and stainless steel-304 are resistive to corrosion, the dissociation products of methanol and ethanol must be corrosive to aluminum, nickel and their alloys. It is not clear why copper wire did not show fast aging. One possible

explanation is that aluminum, nickel and copper are all oxidized in the process of aging. The gas gain drops with aluminum and nickel because Al_2O_3 and NiO are not conductive, thus dropping the electric field. CuO is a semiconductor; therefore, the electric field on the wire is not affected. Gold, platinum and stainless steel are not oxidized; their surfaces stay clean and show no measurable aging.

Isopropyl Alcohol:

Why does the argon-ethane-isopropyl alcohol gas mixture not cause aging on any of the above mentioned wires? The answer may be that isopropyl alcohol gas dissociates differently than ethanol and methanol do. In the first stage of dissociation⁵, isopropyl alcohol will loose two of its hydrogens and become acetone:



As the gas flows through the chamber, the water and the acetone molecules are vented out of the chamber. Experimental evidence confirms this hypothesis. An oxidized copper wire was used as an anode in the argone-ethane-isopropyl alcohol gas mixture until 0.1 C charge was collected from the collimated

regions using the same method mentioned previously. Then the wire surface was examined. The oxidation was greatly reduced especially in the region of the source collimation.

We know that ethane dissociation products polymerize. Therefore, most of the UV quenching must be done by the isopropanol molecules for the above mentioned reactions to be useful in greatly improved life-times.

Several of the experiments repeatedly showed that equal portions of argon and ethane with about 0.25% isopropyl alcohol gas mixture provides very long life-times in drift chambers. An important question is how good a drift chamber gas is for electron drift velocity saturation. Figure 10 shows electron drift velocities as a function of isopropyl alcohol temperatures. For this the single cell drift chamber⁶ was used with a nitrogen UV-laser. The UV-beam was collimated to 400 μm and was precisely positioned to several cm distances to provide precise measurements. The drift velocity is saturated above 900v/cm, independent of the alcohol temperatures.

In the cases of methanol and ethanol it is possible that formaldehydes (CH_2O) and formic acid (CH_2O_2), and acetaldehyde ($\text{C}_2\text{H}_4\text{O}$) and acetic acid ($\text{C}_2\text{H}_4\text{O}_2$) result as dissociation products which can react with aluminum and nickel but not with gold, platinum, and stainless steel.

Acknowledgements:

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Figure Captions

- Figure 1 Cross section of the test chamber.
- Figure 2 Pulse height of 5.9 keV line from the Fe^{55} source as a function of integrated charge indicating the aging process. Stablohm wire with 50% A/50% C_2H_6 gas bubbling through $\text{CH}_3\text{CH}_2\text{OH}$ at -7°C , adding $\sim 1.1\%$ vapor.
- Figure 3 Pulse height resolution, FWHM, is degraded as the Stablohm wire is aged.
- Figure 4 Aging is greatly reduced with isopropyl alcohol (2-propanol). About 0.25% isopropanol vapor added to the A- C_2H_6 gas mixture instead of ethanol. Figure 4(a) shows the Fe^{55} spectrum at the beginning and Figure 4(b) after accumulation of 0.6 Coulomb/cm wire. The drop in the gain is only 5%.
- Figure 5 The Stablohm wire with the addition of 2% Methanol, CH_3OH , to the A- C_2H_6 gas. Very rapid aging is observed. Spectrum (a) is taken before the aging test and spectrum (b) is after only 0.008 Coulomb/cm wire.

- Figure 6 Aluminum wire (Al 5056) with the 2% ethanol added A-C₂H₆ gas mixture.
Figure 6(a) the pulse height spectrum before aging,
Figure (b) after 0.001 C charge per cm,
Figure (c) after 0.003 C.
- Figure 7 Nickel is aged slower than aluminum.
Figure 7(a) before the run,
Figure 7(b) after 0.05 C/cm.
- Figure 8 Scanning electron microscope pictures.
Figure 8(a) nickel wire surface,
Figure 8(b) of the aluminum.
Right hand sides on the aged sections and left hand sides from the sections which are 2cm away from the aged portions. There is no observable increase in diameter of the wires. Appearance of corrosion may be observable.
- Figure 9 X-ray spectra of aluminum and nickel wire surfaces from the aged sections taken during the scanning electron microscope analysis. There is no substantial element observable above aluminum mass. Only the expected elements in the wires are seen.
- Figure 10 Drift velocity as a function of electric field at various temperatures of 2-propanol (isopropyl alcohol) as the 50% A/50% C₂H₆ is bubbled through. The drift velocity is well saturated above 900 v/cm and is independent of the alcohol vapor concentration above this field value.

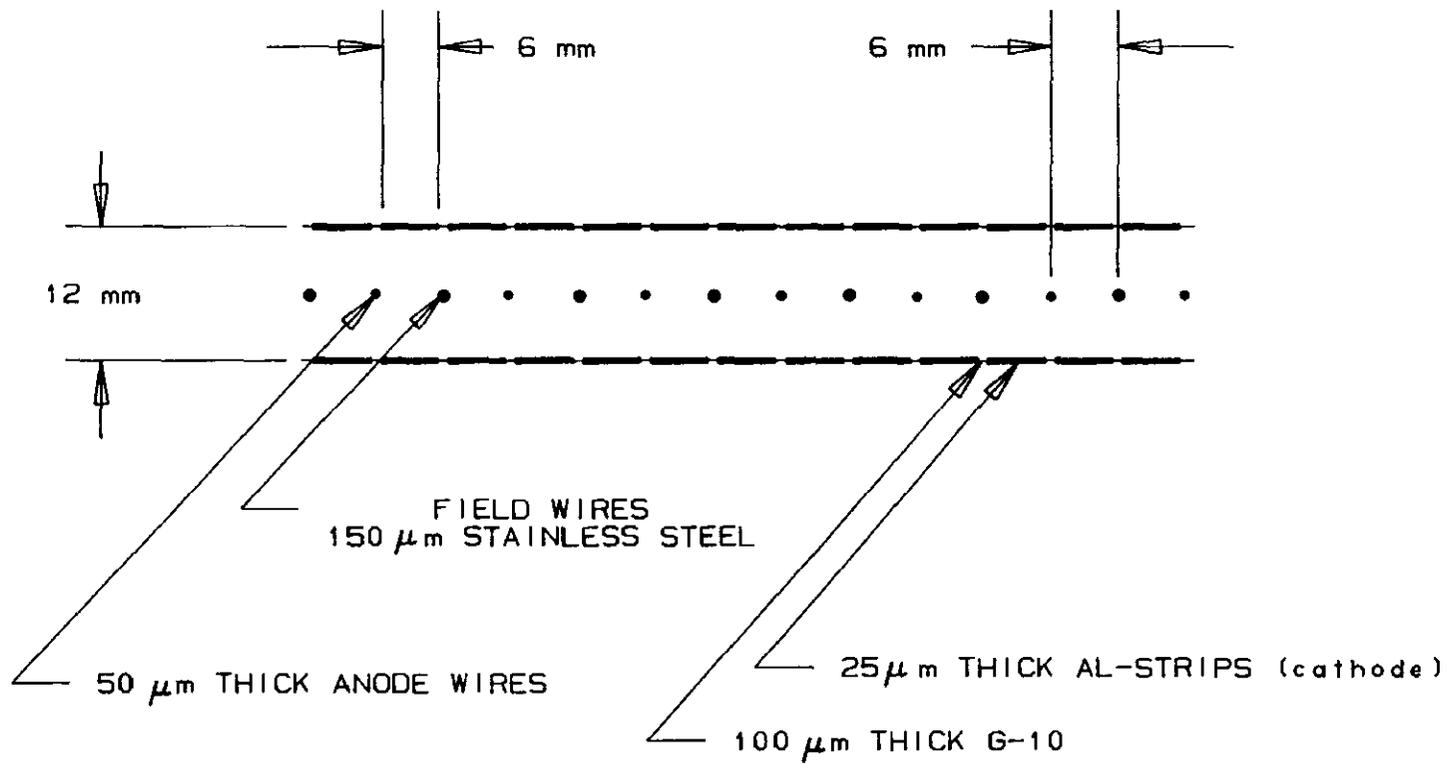


Figure 1

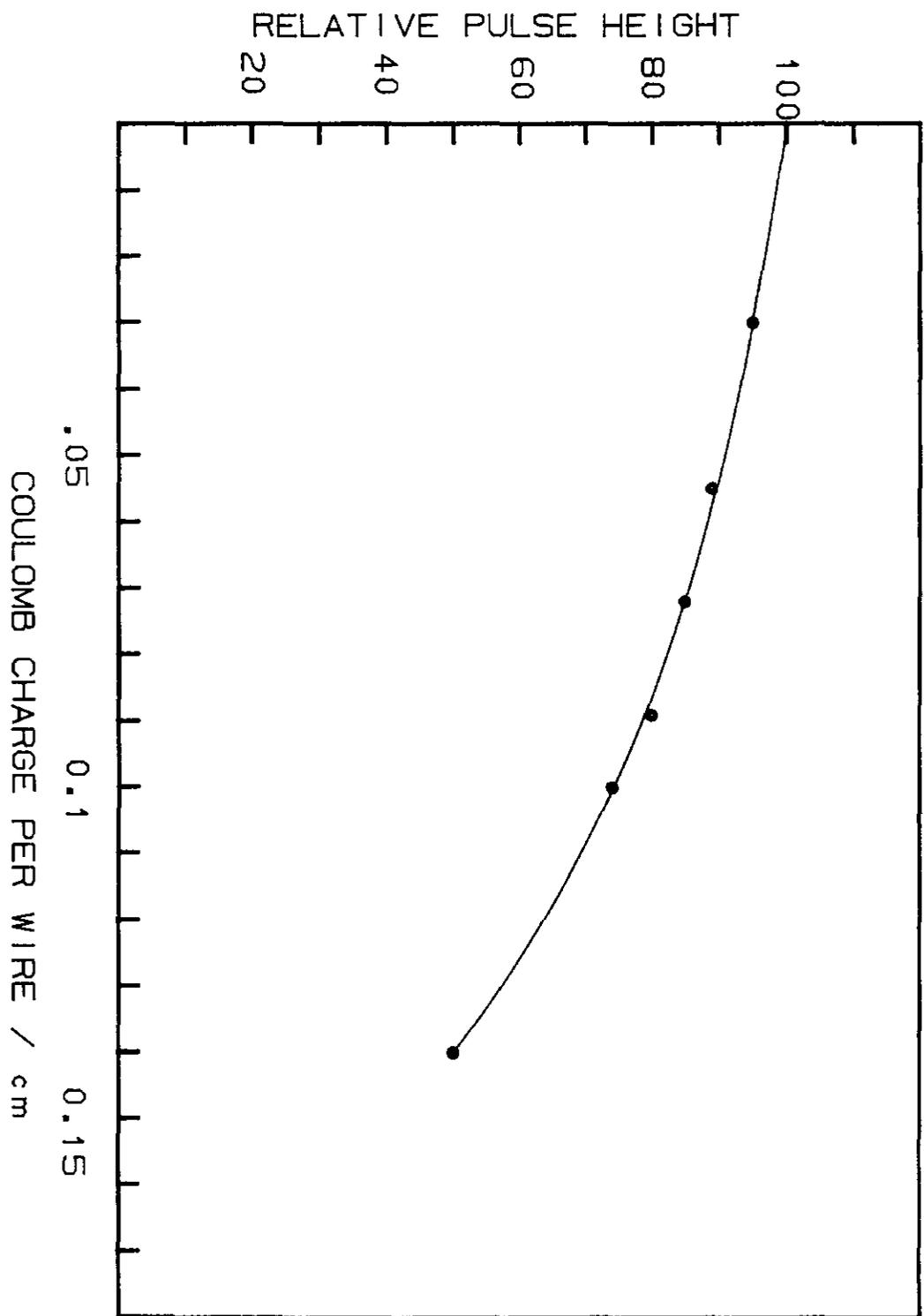


Figure 2

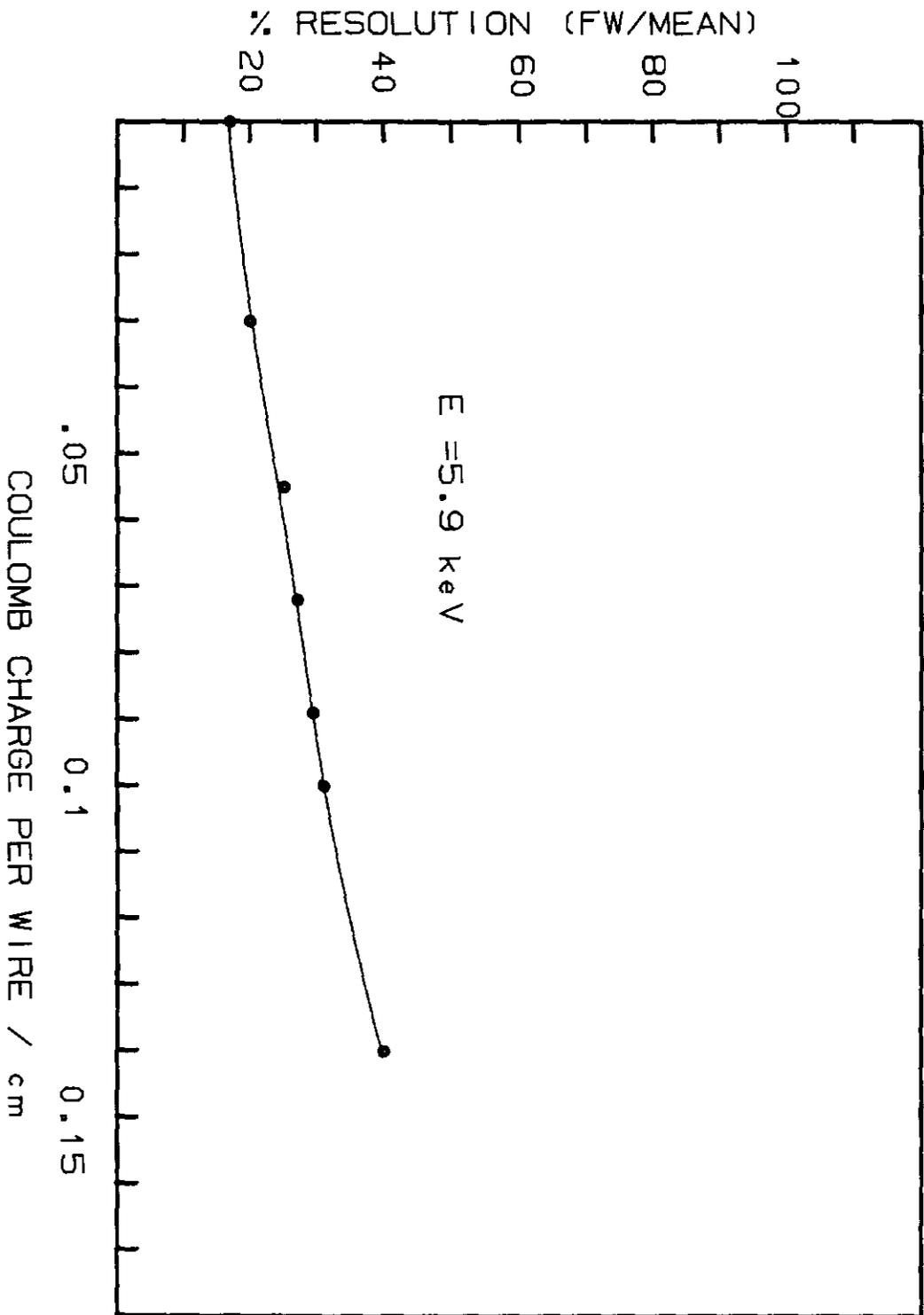


Figure 3

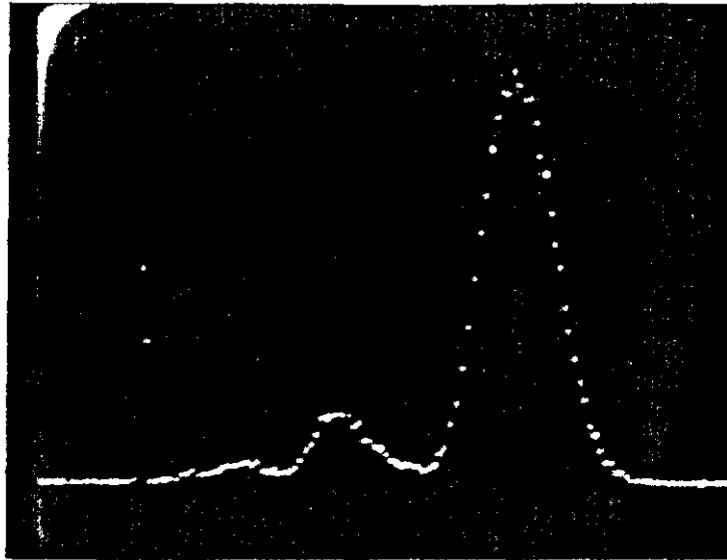


Figure 4(a)

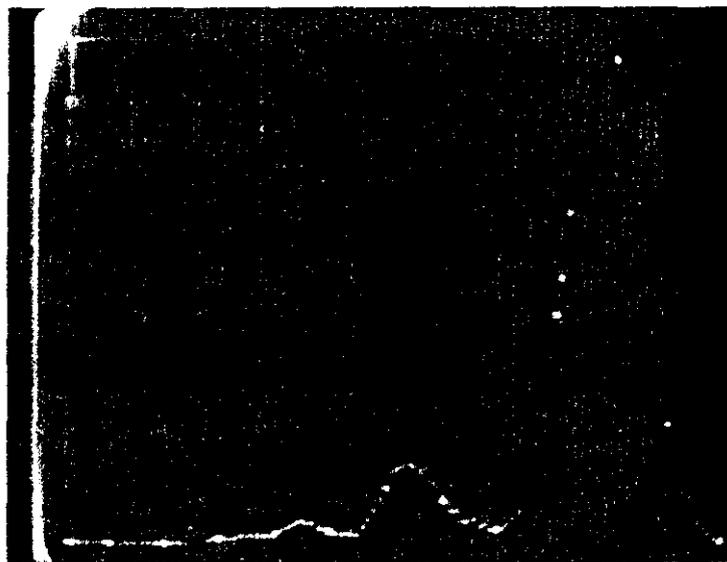


Figure 4(b)

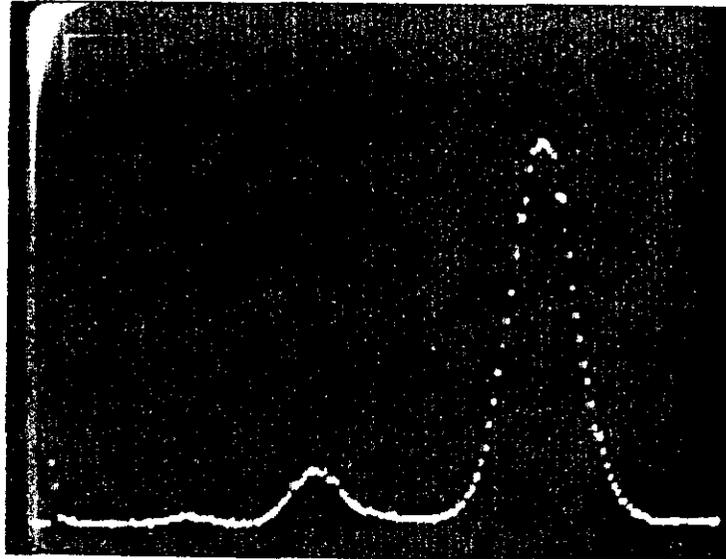


Figure 5(a)

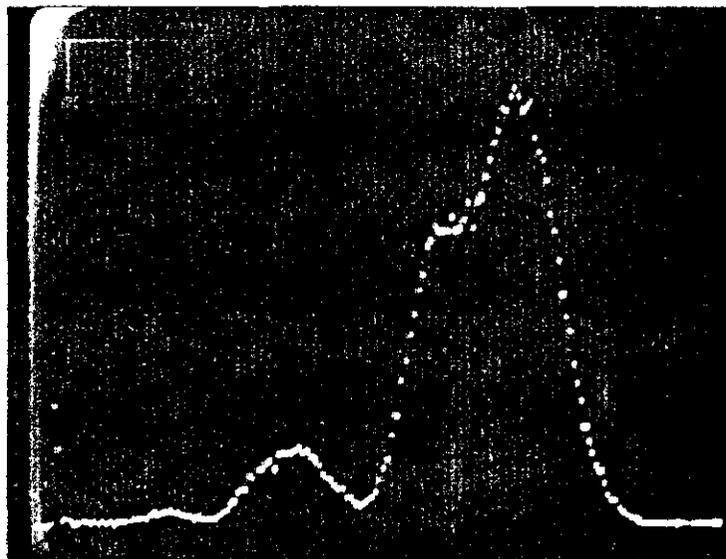


Figure 5(b)

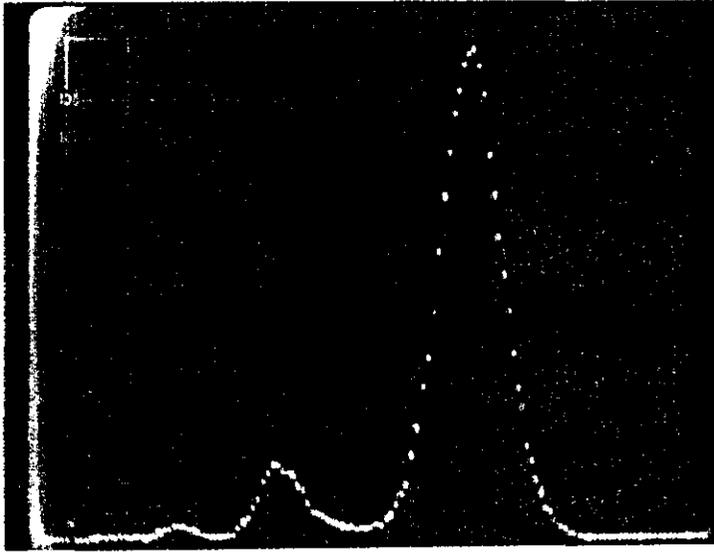


Figure 6(a)

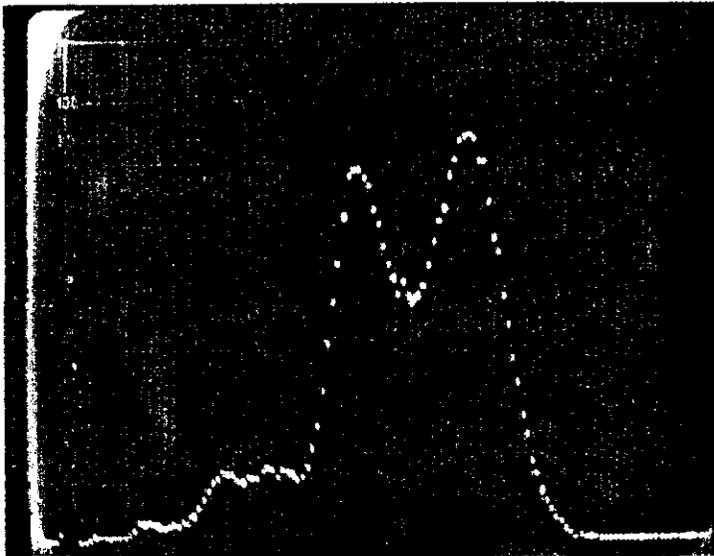


Figure 6(b)



Figure 6(c)

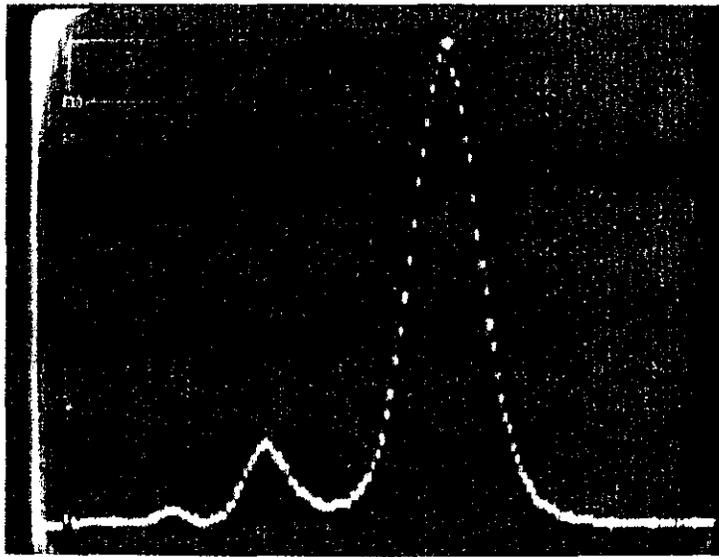


Figure 7(a)

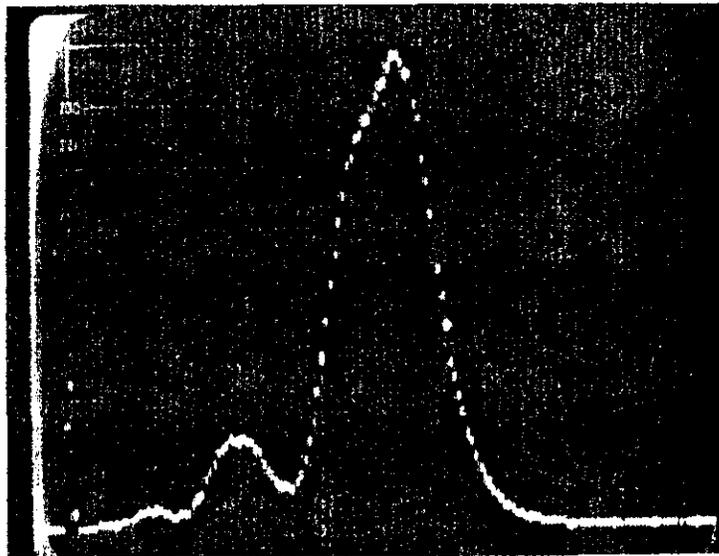


Figure 7(b)

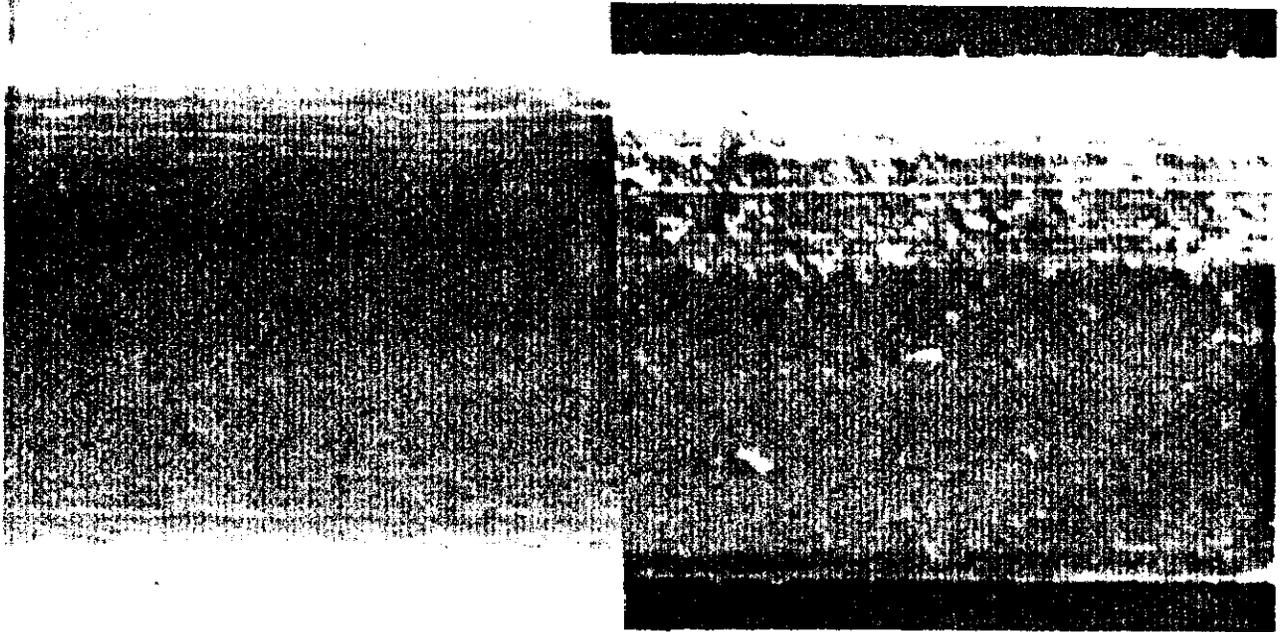


Figure 8(a)

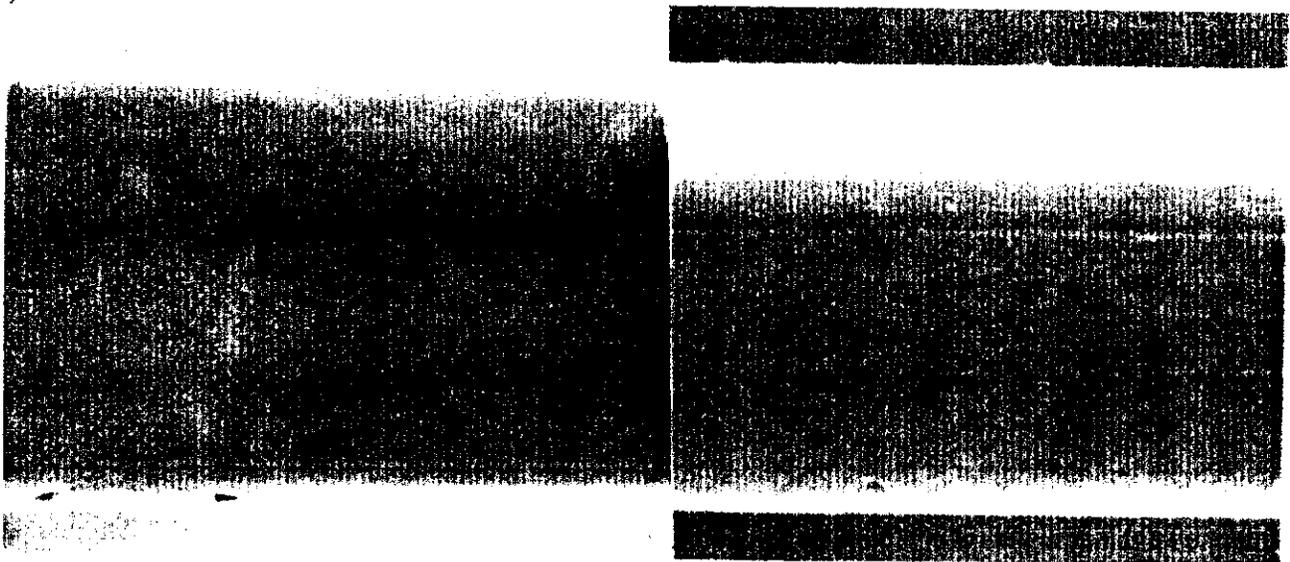


Figure 8(b)



Figure 9(a)

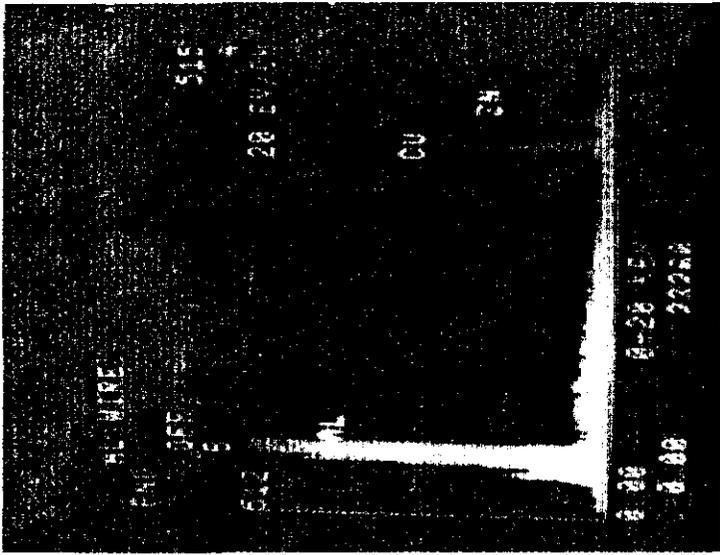


Figure 9(b)

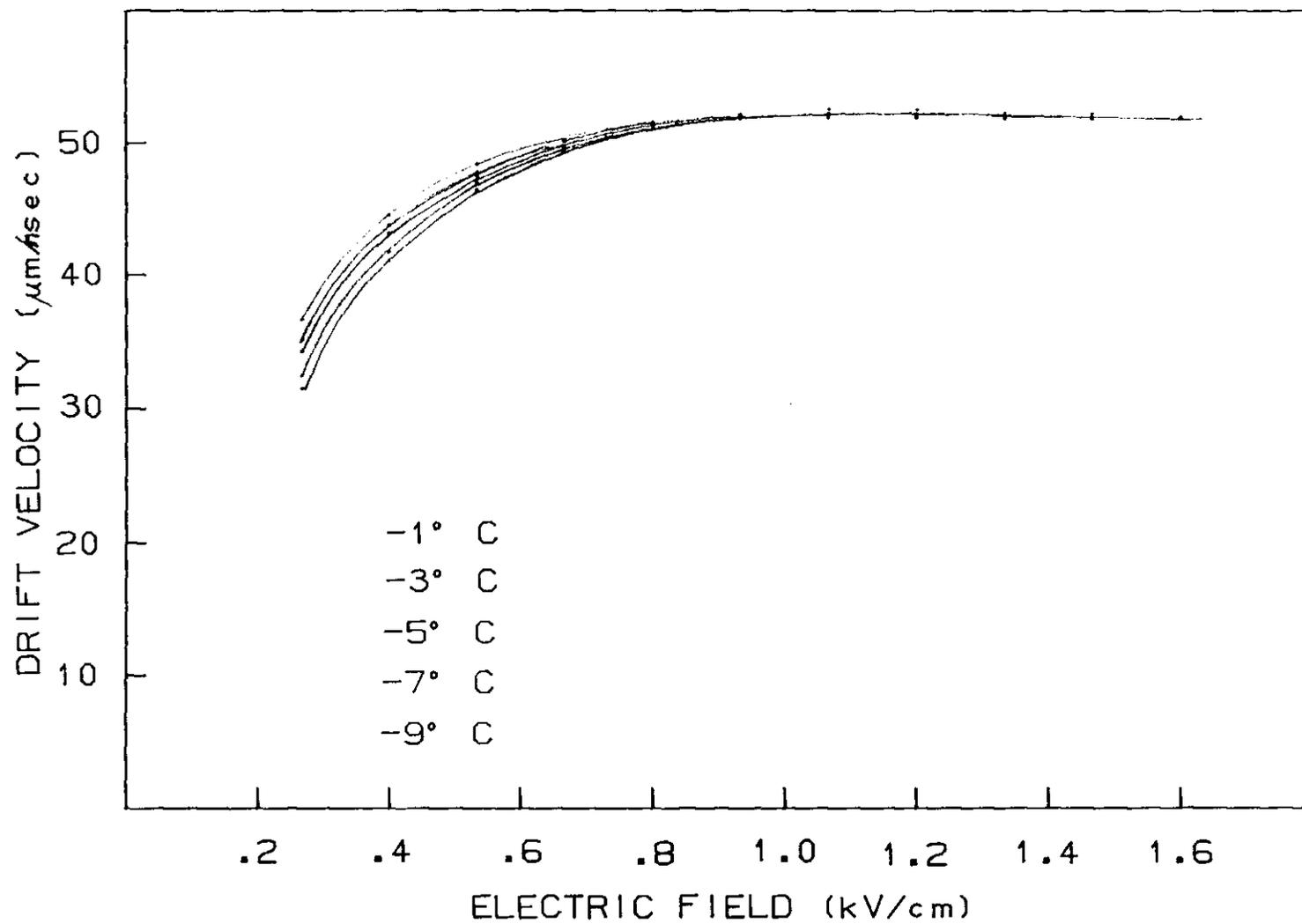


Figure 10