Aging measurements in wire chambers

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Abstract

A study of aging with DME, argon/carbon dioxide and carbon dioxide/isobutane was performed. The influence of the drift chamber construction materials, gas seal pastes and tubes on the aging rate was investigated. The radiation hardness of the KEDR drift chamber cell with DME was increased by an order of magnitude by appropriately selecting drift chamber and tubing materials. The gain dependence of the aging rate with dimethylether (DME) was measured. An influence of the sense-wire surface quality on aging was observed. For the explanation of this results a model of polymer film formation and growth was proposed and tested.

1 Introduction

The tests reported here were begun in an attempt to measure the gain loss due to radiation-induced aging that would be relevant to a drift chamber in the KEDR detector [1] operated with dimethylether gas(DME) at the VEPP-4M [2]. These studies were broadened to include the influence of outgassing from certain materials on the aging rate, a variety of gases and to study a number of parameters and conditions that affect the aging. During this measurements an influence of wire surface quality on aging was found. A broad range of morphologies is associated with the wire deposits as observed under an electron microscope and some connection between the morphologies and the conductivity of the deposits was found. A model of polymer-film formation and growth was proposed and tested.

1.1 Parameterization of aging tests

Commonly used procedures for aging rate measurement systematically underestimate the aging rate. A more correct procedure was proposed previously[3] and is used for these measurements.

The collimated β rays of a ^{90}Sr isotope were used for irradiation of the test chamber to exclude possible dependence on particle type. The total collected charge was determined by integrating the continuously recorded anode current. Currents of $(0.2-3.0)\mu A/cm$ were used. The radiation profile along the wire direction was about $20mm$ FWHM. At the beginning of every test, and at roughly 24 h intervals, the pulse height spectra on the anode wire were recorded, both at the control and the test positions using a low-intensity ^{55}Fe source to avoid the current density dependence (see Ref. [3]). The HV was lowered, before taking the

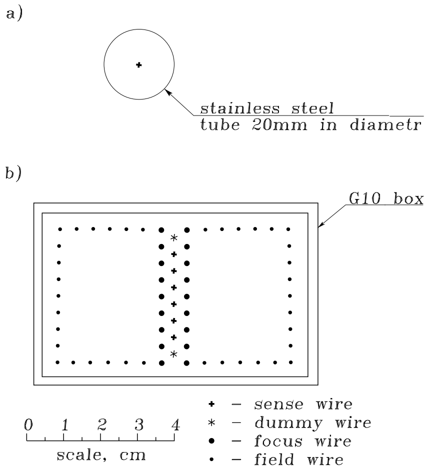

Figure 1: Cross section of the test chambers: a) drift tube; b) DC cell.

pulse height spectra, to avoid saturation effects of the gas gain (see Ref. [3]). The change in the gain was found by comparing the ^{55}Fe pulse height at the test position to that at the control position. The aging rate was parameterized in the form

$$R = -\frac{1}{G_0}\frac{dG}{dQ} = -\frac{1}{A_0}\frac{dA}{dQ}, \tag{1}$$

where G_0 and A_0 are the initial gas gain and the initial Fe^{55} pulse height, dG and dA are the drop of gas gain and pulse height over the test period and dQ is the corresponding charge collected per unit length.

2 Experimental setup

The experimental test cells are shown in fig. 1. One cell is a drift tube with a gold-plated tungsten anode wire $28\mu m$ in diameter and a cathode made of a $20mm$ diameter stainless steel tube cleaned with alcohol. The other one is a drift chamber (DC) cell of the same materials (the same fiber glass/epoxy walls and the same gas seal paste), with geometry and design as in the DC of the detector, and enclosed in a box made of the same materials as the DC walls. All wires are $30cm$ long.

The cell (fig. 1) contains eight anode wires. Six of these wires are sense wires, the other two wires are dummies. The dummy wires help to shape the electric field of the cell. The anode wires are spaced 4.5 mm apart in the radial direction. There are two parallel rows of focusing wires at the left and right of the anode wires. The distance between the rows of focusing wires is $7mm$. The gas gain changes when the high voltage on the focusing wires is changed. The field wires define the region from where the ionization is collected. A uniform

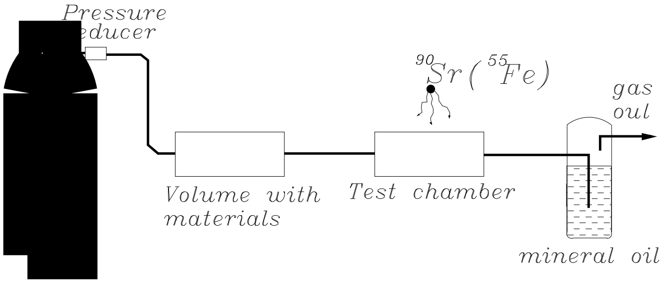

Figure 2: Gas system.

electric field in the drift cell is formed by a distributed potential on the field wires. The field wires are spaced approximately with a $4.5mm$ pitch. We use 150μm diameter gold-plated titanium wires for field, focusing and dummy wires. The wires are used for only one test and afterwards the chamber is restrung.

The field on the sense wire in the test cell is approximately 320 kV/cm at nominal setting. The surface fields on the focusing wires range between $5kV/cm$ to $9kV/cm$, while at the field wires it varies from $13kV/cm$ to $54kV/cm$. Such large surface fields on some of the cathode wires could lead to chamber breakdown [4], and it has been recommended that they be kept below $20kV/cm$ in Argon based gases. However, it has not yet been determined if the $20kV/cm$ rule applies to a DME gas, and no adverse effects are yet evident.

The tests are performed using hydrogen-fired copper pipe (fig. 2 and a mineral oil bubbler at the line output. The gas flow rate is adjusted in order to change the gas in the chamber once per hour and equals 2.5 liter per hour. The current density during the tests was about 0.2μ A/cm.

The effect of aging due to the gas impurities from the different materials is investigated with a proportional tube (Fig. 1a). The gas flows through the volume with a material to be tested and then enters the chamber (Fig. 2). Pure DME does not polymerize [5] and the measured value of R for the tube is $0.7\%/(C/cm)$ in pure DME without testing materials. The aging rate is measured for all tubes before using them in the tests and the tubes with R near this value are selected for testing materials.

3 Aging test results

Table 1 summarizes the results of the material tests with DME gas using the proportional tube and DC cell. The first test was done with the drift tube without any materials. The value of $R = 0.7\%/(C/cm)$ indicates that wire chamber operation with negligible aging can be achieved with our DME gas [6]. When we did not clean the inner surface of the stainless tube with alcohol the measured value of R increased to $17\%/(C/cm)$. The differences in these results indicate that the wire aging may be greatly accelerated by the presence of contaminations at low concentration levels.

An aging run with the DC cell was made under operating conditions as described above.

Chamber type	Tested material	Charge dose C/cm]	R $[\%/(C/cm)]$
DC cell	before material selection	0.6	490 ± 7.3
Tube	without material	2.8	0.7 ± 0.3
	PVC tube (black)	0.1	95.0 ± 2.5
	PVC tube (black) after cleaning	0.4	1.2 ± 0.5
	PVC tube(medical)	2.8	0.8 ± 0.3
	Teflon tube	1.1	5.5 ± 0.3
	gas seal paste(1)	0.8	6.0 ± 0.6
	gas seal paste(2)	0.6	2.0 ± 0.3
	gas seal paste(3)	0.5	22.6 ± 0.5
	gas seal paste(4)	0.5	66.2 ± 1.5
	silicon oil	3.0	1.2 ± 0.6
	mineral oil	3.0	0.4 ± 0.5
	fiber glass/epoxy	0.95	9.5 ± 0.7
	epoxy	0.95	5.4 ± 0.3
	α-naphtylamine	0.6	1.4 ± 0.4
DC cell	after material selection	1.0	45.0 ± 2.7

Table 1: Aging tests with DME.

A value of R of $490\%/(C/cm)$ was observed.

In order to determine the source of the contaminations, we investigated the influence of different construction and of tubing materials on the aging rate with DME gas. All the tests for the different materials were performed with the drift tube (Fig. 1a).

Three types of commonly used plastic tubing, 10 m long, one tubing for each test, were introduced upstream of the test proportional tube and the aging rate was measured. As can be seen from Table 1, very different aging is observed for these three tubings. The best result of $0.8\%/(C/cm)$ was obtained for polyvinyl-chloride (PVC) tubing used in medicine. However, for the other type of PVC we observed a very strong effect on the chamber aging ($R = 95\%/(C/cm)$). When the PVC tubing was removed from the gas system, a wire previously aged was subsequently restored by irradiating it under DME flow. The gain rises with R equal to $-20\%/(C/cm)$ as the deposits are evaporated from the anode wire surface. Similar etching of wire deposits by CF_4 containing gas mixtures results were reported [7, 8]. The same very strong influence of this type of PVC tubing on the chamber aging was measured with $Argon/CO_2$ (92/8). The aging rate here was $31\%/(C/cm)$ and $95\%/(C/cm)$ without and with PVC tubing, respectively. The PVC tube was removed from the gas system, washed with very pure n-pentane and reinstalled in the gas system. A very small value of R ($R = 1.2\%/(C/cm)$) was measured in this case with DME. We can conclude that the pollution on the inner surface of the tube are the main cause for aging in this case and they increased the aging rate about 100 times! Satisfactory results were obtained with Teflon tubing ($R = 5.5\%/(C/cm)$).

Satisfactory results were obtained with the basic DC construction materials fiber-glass/epoxy composites and epoxy of $R = 9.5\%/(C/cm)$ and $R = 5.4\%/(C/cm)$, respectively, and for two types of gas seal pastes $R = 6.0\%/(C/cm)$ and $R = 2.0\%/(C/cm)$. For the third and fourth type of gas seal pastes very bad aging rates were measured $R = 22.6\%/(C/cm)$ and $R = 66.2\%/(C/cm)$, respectively.

Oils can contaminate gases and influence aging effects. As can be seen from Table 1, there was very little aging observed for a silicone diffusion pump oil (PFMS), and a mineral oil (VO-1).

We also tested the aging properties of an additive with low ionization potential α-Naphthylamine [9] used for direct laser calibration of drift chambers. The vapor pressure of α-Naphthylamine at room temperature is only $2.7*10^{-4} torr$ resulting in a very low concentration in the gas ($360 ppb$). Negligible aging was observed for this additive ($R = 1.4\%/(C/cm)$. This is many times better than the aging rate measured with tetra-methyl-phenylene-diamine (TMPD, also known as “Wurster’s Blue”). The measured value of R is $800\%/(C/cm)$ at the 1ppb level of this additive in a $Argon/Ethane$ (40/60) gas mixture [10].

We also tested the gas mixtures: $CO_2/Isobutane$ (85/15) and $Argon/CO_2$ (92/8) and obtained R value of $210\%/(C/cm)$ and $31\%/(C/cm)$, respectively. These results agree well with conclusions reported in Ref. [5] that gas mixtures containing Noble gases and non-polymerizing components have about ten times smaller aging rates in comparison with gas mixtures based on hydrocarbon gases.

The rate of gain loss was found to depend on the several parameters including the avalanche gain: as the gain and consequently the current density is increased, the value of R decreases, other conditions being held constant. Several examples of this behavior can be found [11, 4]. The gain dependence of the aging rate was measured with the proportional tube under DME gas and Vikcint as a polluter using different parts of the anode wire. The gas flow rate was equal to 2.5 l/h. We changed the voltage on the tube and measured the R value for different current densities (fig. 3). A difference in aging rate of a factor of two was obtained when the current density was changed by an order of magnitude.

After the first test, the DC cell was opened and washed with gasoline followed by alcohol. Only PVC pipe used in medicine was used for the connections and mineral oil in the bubbler. The second test with DME was done with a newly strung chamber, with the same operating conditions as in the first test. For the second DC cell test, a gain loss $45\%/(C/cm)$ was observed (see Table 1). This is an order of magnitude better than in the first test. However, after $1.2 C/cm$ of accumulated charge we observed a noise signal with a small amplitude. This can be interpreted as the Malter effect [12].

4 Test of the KEDR drift chamber

Our results show that impurities in the gas mixture can increase the aging rate many times and distort the results of aging rate measurement carried out on prototypes in comparison with real drift chamber conditions. Therefore, when the DC was built and installed in the

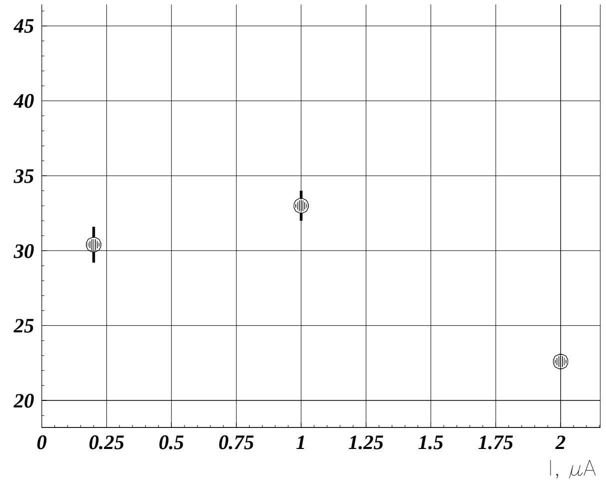

Figure 3: Aging rate versus current density.

KEDR detector a measurement of the aging rate with a proportional tube placed downstream of the DC was carried out. At that point all pollutions from the DC, gas system materials and tubing are present. The standard gas flow rate of three DC volumes per day was set up. A value of $R = (7.3 \pm 3.0)\%/(C/cm)$ was measured. The smaller R value obtained for the DC in comparison with the DC prototype ($R = 45\%/(C/cm)$) can be explained by a smaller ratio of DC surface to chamber volume resulting in a smaller concentration of impurities in the gas from outgassing DC construction materials.

The measured relative gain drop corresponds to a 0.3% pulse height decrease per year at a gain of $2 * 10^5$ for a flux of charged particles of $1 kHz/cm^2$. Such conditions are acceptable for the DC.

5 Influence of sense wire surface quality on aging

An interesting effect was found when a testing material (gas seal paste(3) (Vikcint), see Table 1) was introduced into the gas system after the the proportional tube had been checked in clean conditions up to about $0.45 C/cm$ and irradiation was continued at the same part of the sense wire. A practically zero aging rate (plateau independence) was observed up to $(0.2 - 0.3) C/cm$ charge collected; then the amplitude started to drop with a rate $R = (11.5 \pm 0.9)\%/(C/cm)$.

The aging rate measurement for the part of the sense wire that was not irradiated before in clean conditions gave the value $R = (22.6 \pm 0.5)\%/(C/cm)$. The measurement was carried out on the same tube and with the same testing material. The value of aging rate measured

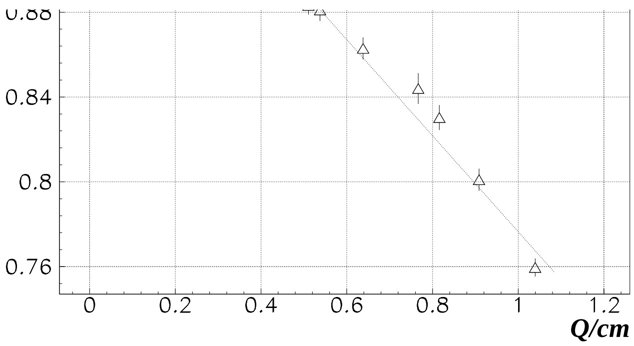

Figure 4: Normalized pulse height of 5.9 keV line from ^{55}Fe source as a function of integrated charge with DME. Measurement with testing material without preliminary irradiation in clean conditions (triangles) and after preliminary irradiation in clean conditions (filled circles).

for the previously irradiated part of the sense wire is about two times smaller in comparison with the non-irradiated one. Both effects are clearly visible in fig. 4. To check this effect the same measurements were carried out with epoxy and fiber glass/epoxy. The same results (a plateau in amplitude behavior and smaller aging rate for the previously irradiated part of sense wire) were obtained in both cases. In all these measurements Vikcint was used as a polluter. A current of $2\mu A/cm$ and a gas flow rate of 2.5 l/h were used in all measurements.

Figs. 5,6 show the dependencies of the plateau size (a) and R vs the dose of preliminary irradiation (Q_{prel}). The plateau size (fig. 5) increases with increase of Q_{prel} up to a value $a = 0.25C/cm$ at $Q_{prel} = 0.4C/cm$ and then drops to zero at $Q_{prel} > 1C/cm$. The aging rate (fig. 6) decreases from $R = 22 - 25\%/(C/cm)$ at the values of $Q_{prel} < 1C/cm$ to $R = 11\%/(C/cm)$ at $Q_{prel} > 1C/cm$. We can not explain the low R value measured at $Q_{prel} = 0.13C/cm$.

Based on these results a model was proposed that can explain the plateau in amplitude behavior and the difference in the aging rates. The wire surface quality play important role in this model.

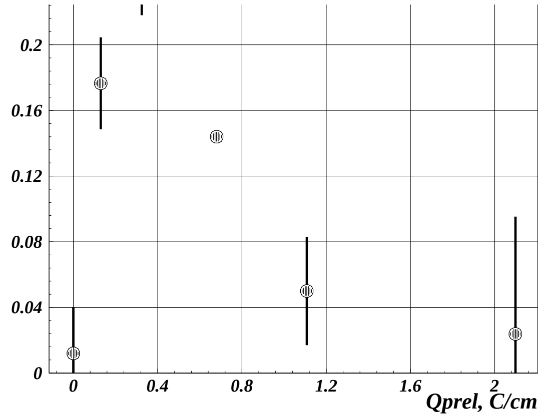

Figure 5: Size of plateau (a) vs dose of preliminary irradiation.

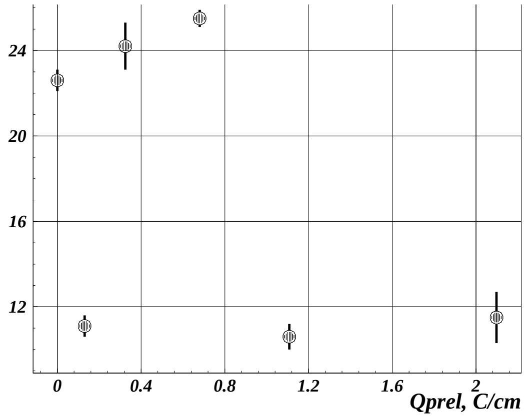

Figure 6: Aging rate (R) vs dose of preliminary irradiation.

6 Model of film creation and growth

The surface of a sense wire is not ideal. Under magnification the wires surface is a set of different types of defects. For simplicity we can imagine the surface of a wire as a set of peaks. The strength of the electric field E is proportional to $1/r$, were r is the radius of the surface curvature. Our model is based on the following assumptions:

1. The average strength of the electric field on the surface of a sense wire for DME gas in working conditions is equal to $300 - 350$kV/cm. The electric field lines collect mainly on the tips of the peaks rather than on the surface between the peaks; the strength of the electric field on the tips can be many times larger. Therefore, the main part of electrons and negatively charged polymers from an avalanche reach the sense wire surface in these places. As a result the process of polymer-film formation starts on the surface of the tips in the regions with highest electric field strength. By means of an electron microscope this assumption was proved. Polymer fibers in an early stage of growth are shown in fig. 7. It is clearly visible that the fibers grow on point-like defects of the surface and that the distribution of fibers on the surface is not homogeneous and depends on the number of defects per surface square.

2. The probability that charged polymers stick to the metal surface after a neutralization process on the gold-plated surface is small and in principle can depend on the velocity of the polymer which is a function of the electric field. After creation of the first monolayer of polymers the probability for polymers to stick increases many times and the thickness of the film starts to increase rapidly and the amplitude from the sense wire starts to drop. As a result, the amplitude on a sense wire should be constant up to some dose without preliminary irradiation. To check this assumption a measurement was carried out at very low current density $0.2\mu A/cm$ without preliminary irradiation in clean conditions. The result is shown in

Figure 7: Deposits on anode wire at very small dose of irradiation.

fig. 8. The plateau in amplitude behavior is clearly visible and equals $(0.057 \pm 0.008)C/cm$.

3. The average electron energy in the avalanche is of the order of 10 eV resulting in a very high local temperature. The preliminary irradiation in clean conditions with the non-polymerizing DME gas polishes the surface of the sense wire and increases the average radius of the tips and decreases the difference in the heights of the peaks. After that, the field lines are distributed on a larger area of the sense wire surface and the local electric field strength (and consequently the velocity of the polymers) drops. The bombardment intensity decreases and a larger dose of radiation or mass of polymers is necessary for the creation of continuous film on the surface of the tips. As a result, the plateau size starts to increase with increasing dose of preliminary irradiation (fig. 5). At $Q_{prel} = 0.33C/cm$ the plateau size is equal to $(0.24 \pm 0.02)C/cm$ which is about four times larger than the plateau size obtained without preliminary irradiation ($(0.057 \pm 0.008)C/cm$). In principle, the dependence of the probability for a polymer to stick to the metal surface versus the velocity of polymers at the moment of neutralization can play some role in this effect. At $Q_{prel} > 1.0C/cm$ the concentration of polymerizing impurities in DME is sufficient for the creation of the polymer film and the plateau size decrease to zero (fig. 5) at higher dose of preliminary irradiation.

The influence of preliminary irradiation on wire surface quality was investigated. Photographs of the sense wires made with a scanning electron microscope before and after preliminary irradiation are shown in figs. 9,10, respectively. A better surface quality after preliminary irradiation was observed.

4. As was suggested earlier, the polymer film formation starts on the surface of tips in the regions with highest electric field strength. The mass of polymers per unit of surface is proportional to the electric field strength and the growth velocity of fibers has a maximum value at the same points. Therefore, after a certain irradiation dose we should obtain a thickness of film proportional to the electric field strength as shown in fig. 7. The number of field lines collecting on the fiber increases with increasing fiber length. The diameter

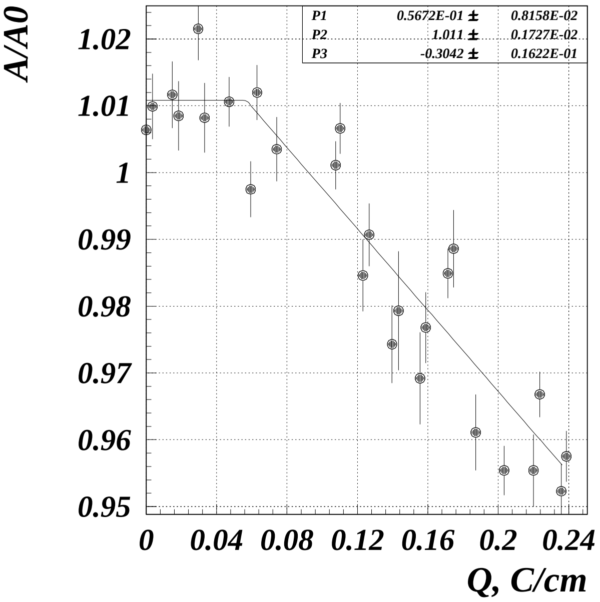

Figure 8: Relative gain versus collected charge on a sense wire without preliminary irradiation.

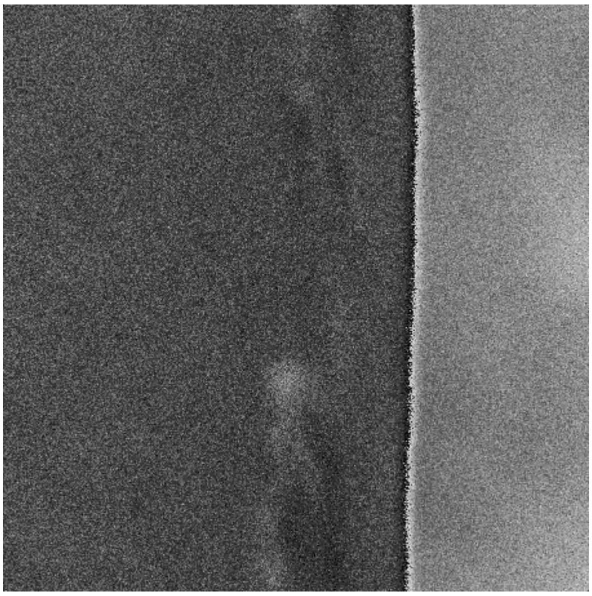

Figure 9: Photograph of sense wire edge before preliminary irradiation. The side of photo is equal to $2\mu m$.

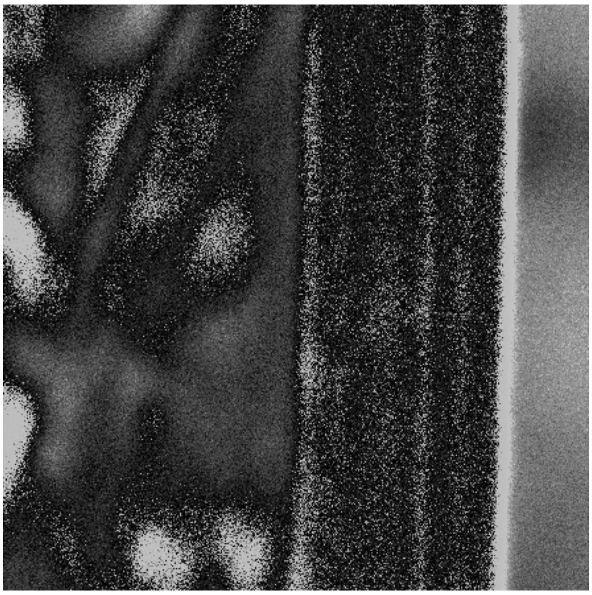

Figure 10: Photograph of sense wire edge after preliminary irradiation. The side of photo is equal to $2\mu m$.

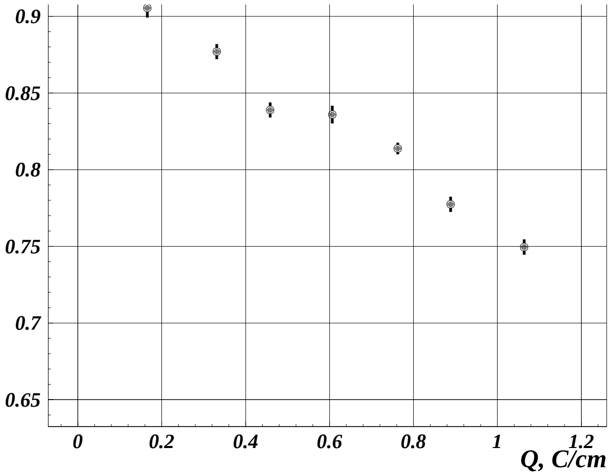

Figure 11: Relative gain versus collected charge on a sense wire without preliminary irradiation.

of the collection region is approximately equal to the length of the fiber. After some dose practically all field lines and polymers will be collecting on the ends of the fibers and the growth of film on the sense wire surface and on fibers with smaller length stop. After that, the effective radius of the sense wire and the drop in gas gain as a result of the aging process depends on the length of fibers and on the number of fibers per surface unit. Therefore, a peculiarity in amplitude behavior can be expected from a sense wire that was observed (fig. 11) in many measurements at a charge value $\sim 0.5C/cm$ (for Vikcint). In principle, we can not exclude that multiplication in the regions with very high electric field near the ends of fibers plays some role in the explanation of this effect.

The preliminary irradiation in clean conditions smoothes the radii and the heights of the peaks. As a result, at a moment when all field lines are collecting on the ends of fibers, the number of growing fibers per surface unit increases and as a consequence the average length of fibers decreases. Therefore, the effective radius of the sense wire and the drop of the amplitude from the sense wire are smaller at the same dose of irradiation (fig. 6).

5. The tests of different materials with DME gas and other gas mixtures give a lot of examples for deposits. The most typical types of the anode wire deposits are shown in figs. 12,13,14,15,16, 17. In all cases a film was found on the anode wire surface. The form of the fibers on these films vary: thin fibers (fig. 12), thicker cylinders (fig. 13), cylinders with spheres on the ends (fig. 14), tree-like whiskers (fig. 15), thick film with small growths (fig. 16), and a practically smooth cover (fig. 17).

The model of polymer-fibers growth is correct only in the case of very good polymer conductivity. In reality, in many measurements bad conductivity of polymer film was found

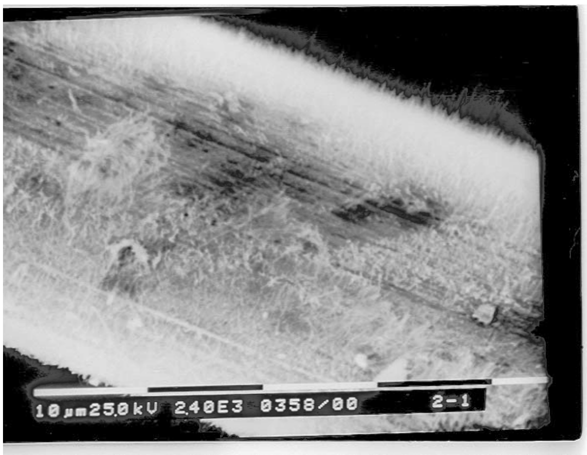

Figure 12: Deposits on anode wire (DME+Teflon).

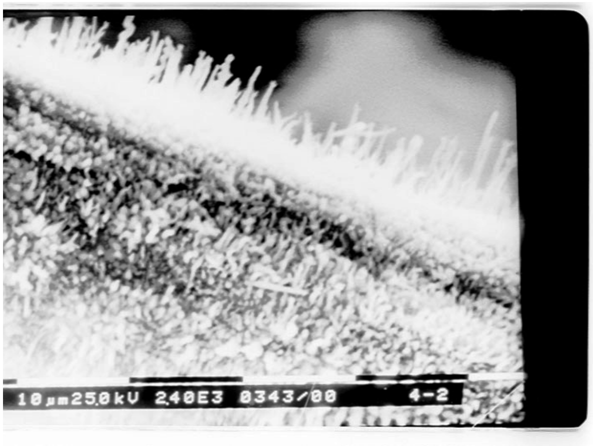

Figure 13: Deposits on anode wire (DME+epoxy).

Figure 14: Deposits on anode wire ($CO_2/Isobutane$).

Figure 15: Deposits on anode wire ($CO_2/Isobutane + PVC$).

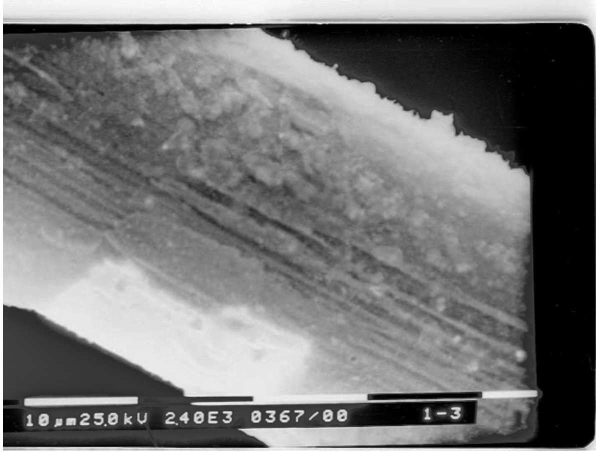

Figure 16: Deposits on anode wire (DME+PVC).

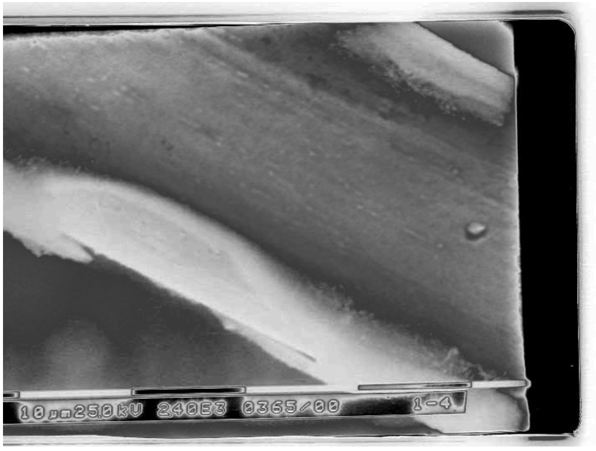

Figure 17: Deposits on anode wire (DME+gas seal paste(1)).

[13, 14]. We attempt to understand how the conductivity of polymers influences the fiber growth. For simplicity, examine only one fiber. A fiber on the anode wire surface is positively charged and field lines are collecting on the fiber end. The current of electrons and negatively charged polymers from avalanche are neutralized by positive charge on the end of a fiber. In case of good conductivity the charge is restored, the field line structure does not change and the fiber continues to grow (fig. 12). At low conductivity, the positive charge on the end of fiber is not restored at small fiber length and as a result the field lines and polymer molecules start to move along the fiber in the direction of the wire surface. The diameter of the fiber increase (fig. 13 and under certain conditions some structures can be obtained at the end of the fiber (figs. 14,15). After this increase of diameter the resistance of the fiber decreases and the field lines and polymer molecules start to move back to the end of the fiber and the fiber continues to grow at full length. At very bad conductivity, the growth of the fiber stops at very small length. The field lines and polymer molecules distribute on the wire surface around the fiber and a smooth film of polymers (figs. 16,17) forms.

The current of electrons and negatively charged polymers is a function of sense wire current density. As a result, at constant conductivity the fiber length and form depends on the gas gain and the intensity of irradiation. Therefore, effective sense wire radius and consequently the aging rate can depend on the sense wire current density.

In an attempt to test this model, the conductivity of polymer films shown in figs. 16 and 17 were qualitatively compared. Better conductivity for the film shown in fig. 16 was observed, which confirms our model. More accurate measurements and computer simulations are necessary.

7 Aging rate measurements with anode wires from different producers

In order to test the influence of surface quality on aging, we carried out aging rate measurements with DME gas and Vikcint as a polluter for anode wires from different producers. A current of $2\mu A/cm$ and a gas flow rate of 2.5 l/h were used in all measurements. Two different 20 μm diameter gold-plated tungsten wires from Russia and USA (used in BaBar drift chamber) and 25 μm diameter gold-plated tungsten wires from Italy were used in these measurements. Photographs of the wires before irradiation are shown in figs. 18,19,20,21, 22, and 23. The sizes of the left and the right photographs equal $40\mu m$ and $8\mu m$, respectively. The Russian wire was gold-plated using gold in liquid phase and as a result this wire has the best surface quality. The wires from Italy and the USA were gold-plated using different galvanic processes resulting in a difference in wire surface structure and quality.

Very different aging rates were obtained for these three wires (Table 2). The best value of $R = (32.0 \pm 1.0)\%/(C/cm)$ was measured for the wire from Russia. Three times larger values of $(88.1 \pm 2.0)\%/(C/cm)$ and $(106.7 \pm 1.6)\%/(C/cm)$ were obtained for the wires from the USA and Italy, respectively. For all wires non-zero and practically equal plateau sizes were obtained with our level of precision (Table 2).

Photographs of wires from Russia and Italy after irradiation are shown in figs. 24,25,26, and 27. The sizes of the left and the right photographs are equal to 20 μm and $8\mu m$,

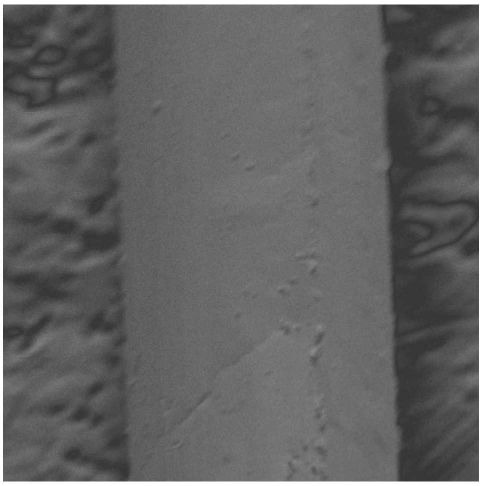

Figure 18: 20 μm anode wire (Russia).

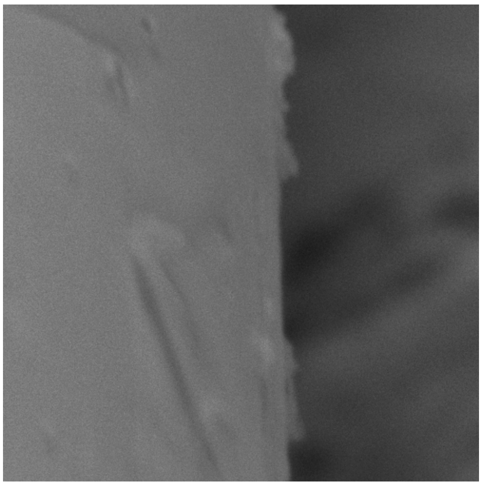

Figure 19: 20 μm anode wire (Russia).

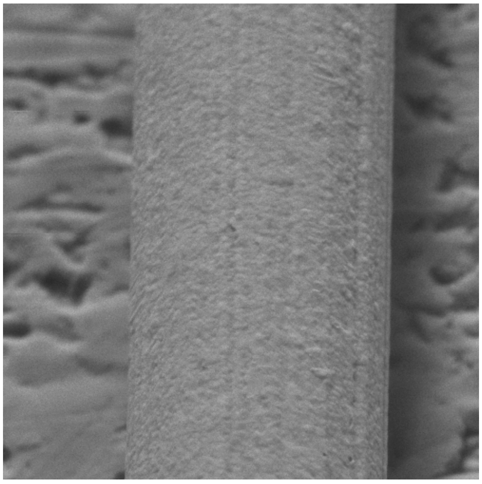

Figure 20: 20 μm anode wire (USA).

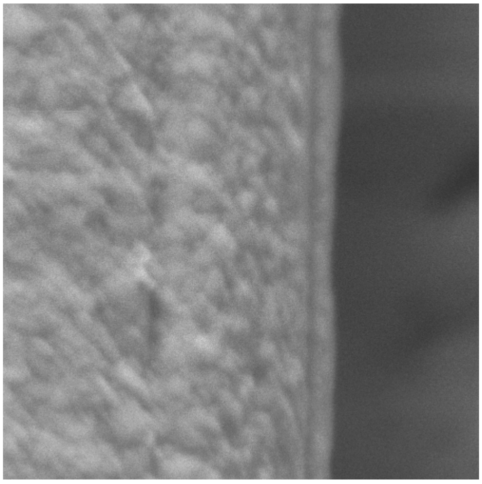

Figure 21: 20 μm anode wire (USA).

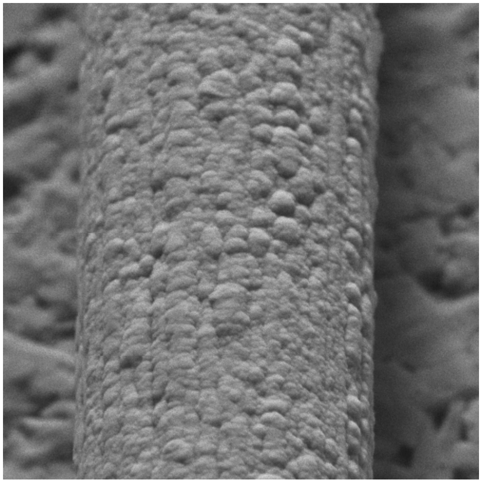

Figure 22: 25 μm anode wire (Italy).

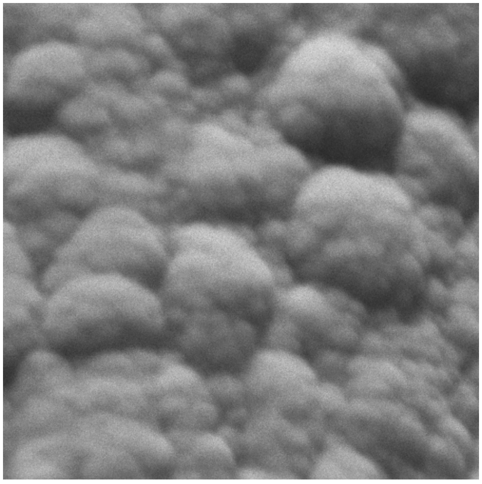

Figure 23: 25 μm anode wire (Italy).

Producer	R, %/(C/cm)	a, C/cm
Russia	32.0 ± 1.0	0.054 ± 0.013
USA	88.1 ± 2.0	0.027 ± 0.006
Italy	106.7 ± 1.6	0.036 ± 0.001

Table 2: Aging rate and plateau size for wires from Russia, USA and Italy.

respectively. In both cases polymer fibers are grown but a difference in the distribution of deposits on the wire surface was found. The fibers on the Russian wire are on the average smaller in length in comparison with the Italian wire. The polymer fibers on the Russian wire are more uniformly distributed on the surface. In case of the Italian wire, the polymer fibers mainly grow from the regions situated between the golf grains and the picture looks like the growth of grass on a lawn with stone plates. Only a small number of fibers was found on grain surfaces. We can explain this fact with better grain surface quality in comparison with the surface between grains. These results confirm our model and show that wire surface quality influences the aging process.

We conclude that the improvement of sense wire surface quality increases the size of the plateau in the amplitude behavior and decreases the aging rate.

8 Summary and conclusions

In relatively clean conditions, very good stability against aging was found with DME gas. The aging rate of this gas is very sensitive to contaminations from the materials subjected to the gas. The influence of different DC construction and tubing materials, and the gas seal pastes on the aging rate were investigated. The radiation hardness of a DC cell with DME was increased by an order of magnitude by a careful selection of DC and tubing materials. We conclude that the DC can be operated without considerable aging effects by choosing appropriate materials. We have demonstrated that the performance of a proportional tube aged in a DME gas with contaminations from PVC tubing was subsequently recovered by irradiating after the PVC had been removed from the gas system. An influence of the sense wire surface quality on aging was observed. For the explanation of this results a model of polymer film formation and growth was proposed and tested. Based on these results we conclude that an improvement of sense wire surface quality can increase the size of the "zero-aging region" and can decrease the aging rate.

9 Acknowledgments

We would like to express our thanks to Prof. A.P. Onuchin for support of this work and V.I. Telnov for fruitful discussions. It is a pleasure to thank A.S. Starostin for technical assistance and for building the test chambers used in this work.

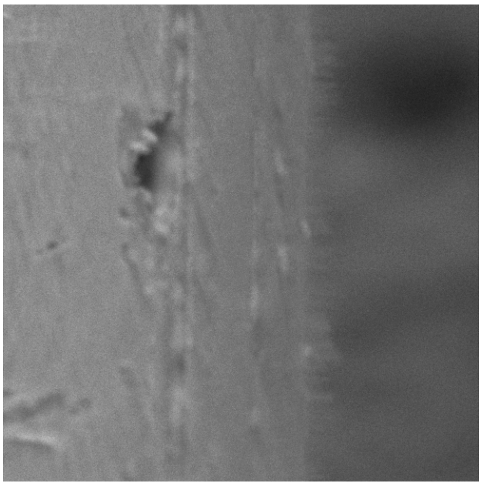

Figure 24: 20 μm anode wire (Russia).

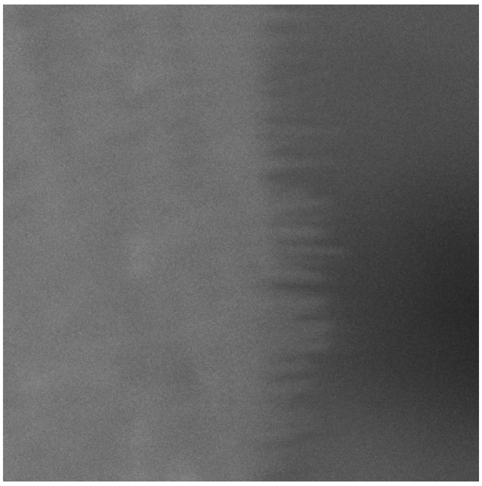

Figure 25: 20 μm anode wire (Russia).

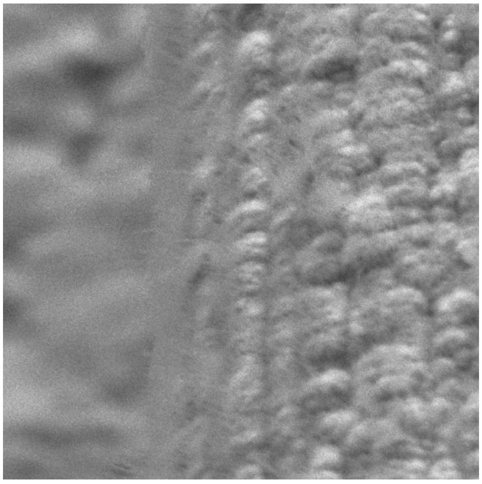

Figure 26: 25 μm anode wire (Italy).

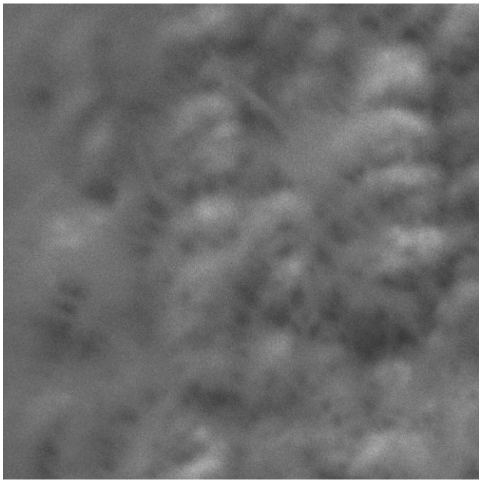

Figure 27: 25 μm anode wire (Italy).

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