Study of field emission and cathode aging in drift chambers.

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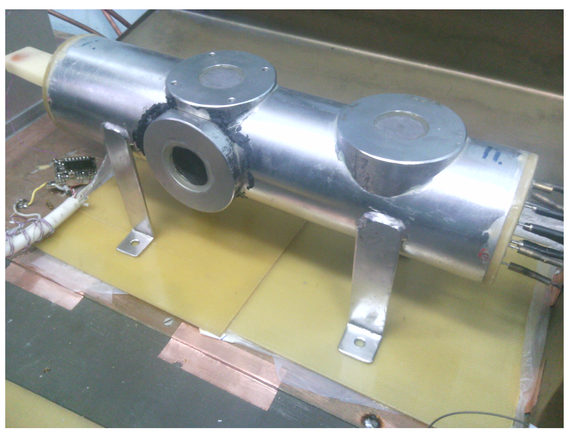
Abstract

Four types of cathode wire samples were tested for the threshold of field emission. Two Ti/Cu/Au wires of USSR production with diameters 150 and 120 microns used in the drift chamber of the KEDR detector at the VEPP-4M collider. Also two Al/Ni/Au wire samples with diameters 120 and 150 microns manufactured by California Fine Wire (CFW) were tested. For 120 microns CFW wire the effects of various surface contaminants on cathode aging and occurrence of Malter emission were investigated.

Introduction

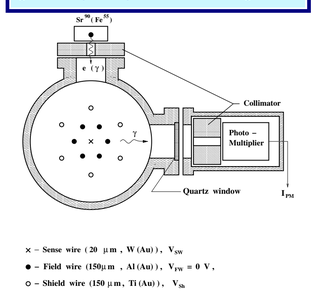
In connection with the manufacturing of a new drift chamber it became necassary to check the surface quality of cathode wire samples from various manufacturers to select the type of wire that is most suitable for use in the new drift chamber of the KEDR detector [1]. This four samples were tested for the threshold of field emission.
As part of a collaboration with BaBar, cathode aging test with a helium-isobutane (80/20) gas mixture for hexagonal drift cell was performed. A similar study was previously carried out in work [3]. Also for cathode aging the effect of various contaminants on the threshold has been studied. During the operation of the drift chamber, positively charged polymers from the avalanche fall on the surface of the cathode wire and form a thin insulating film. A positive charge of film surface gives rise to double charged layer and high electric field strengths in the film, leading to a decrease in the electron work function from cathode wire and occurence of the Malter emission [2].

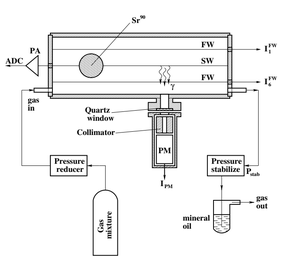
Experimental setup



Anode wire is pulled in the center of the chamber. High voltage of positive polarity is applied to the anode and guard wires. The cathode wires are grounded. Signal from anode wire pass throw the capacitor go to the preamplifier and then digitized.

A section of wire 10 cm from the site of irradiation with the Sr^{90} isotope is observed by a collimated PMT. At the same time the current from the cathode wires and the current from the PMT are recorded.



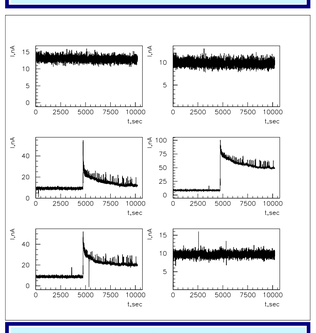


For cathode aging measurements the drift cell was irradiated with the Sr^{90} isotope and the accumulated charge was measured per unit length of the anode wire in mC/cm. When the Malter current appeared its time dependence is measured. In the event of Malter emission it was discovered 30 seconds delay in the current rise from the PMT relative to the current rise from the wires.

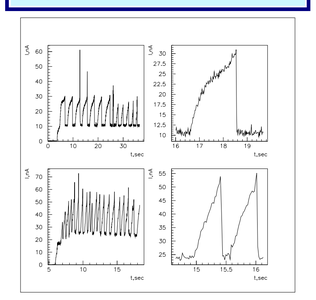
Study of cathode aging

A study of cathode aging with a gas mixture helium-isobutane (80/20) was carried out.

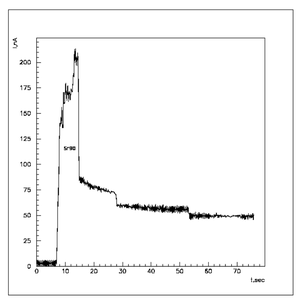
In case of a gas discharge at the beginning of the test arising from poor mixing of the gas mixture a film on cathode wire formed and Malter emmission occured without preirradiation. Fourth wire is electron emitter and currents on the third and fifth are due to charge diffusion in the avalanche near the anode. Over time the electron emission decreased. Similar behaviour was observed in paper [3].



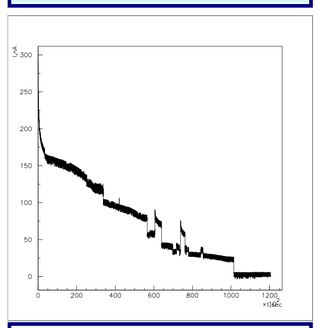
To simulate the wire contamination at manufacturing process one of cathode wires was coated by organosilicon lacquer. At this conditions the Malter emission occured without irradiation. Periodic time dependence of cathode wire current is observed. This behaviour is explained by periodic charging and discharging of the film. On the top pictures (see below) the gas amplification is $7.3 \cdot 10^4$. On the bottom pictures gas amplification is $2 \cdot 10^5$.



In the fingerprint test after the installation of the Sr^{90} isotope a Malter current arised. This stepwise dropping over time is due to the discrete origin of the sources of the Malter emission.



Long-term Malter current dependence. For the time about one day the Malter current drops to zero. Also current kicks associated with the disappearance and appearance of individual emission sources was observed.

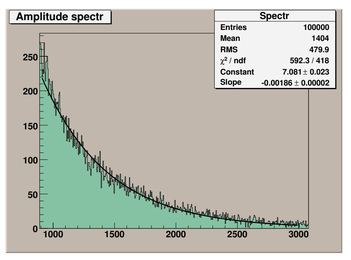


Under pure conditions irradiation Malter emission was not observed up to 800 mC/cm. With vacuum oil contaminated the cathode wire the Malter emission was not observed up to 190 mC/cm. For emulation of gold-plating defects the aluminum coating was used. Aluminum-plated cathode wire have no Malter emission up to 130 mC/cm.

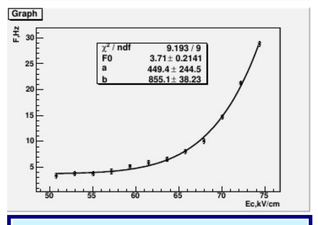
Study of field emission

The field emission threshold was measured with dimethylether gas. To obtain field emission threshold, measured autoemission rate was fitted by the Fowler-Nordheim law [4] with constant term:
$F = F_0 + aE_c^2 e^{-\frac{b}{E_c}}$
Next, the threshold of field emission is found from the condition:
$aE_{th}^2 e^{-\frac{b}{E_{th}}} = F_{th}$,
where the threshold load is F_{th} selected equal to 3 Hz.

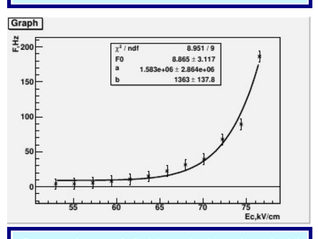
Single-electron spectrum of field emission pulses used to measure gas amplification.



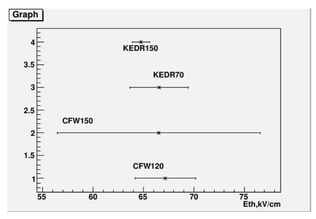
An example of the dependence of single-electron pulses load from cathode wire electric field strength for wire of 150 micron in diameter made in USSR (and used in the KEDR drift chamber).



Single electron pulses load from cathode wire surface field for 150 micron wire manufactured in the USA (by the California Fine Wire Company).



Comparison of field emission threshold for four tested wires.



Conclusions

- In the absence of contaminations on the cathode wire surface, the Malter emission was not observed until the collected charge per unit length of the anode wire reached a value of 0.8 C/cm.
- A gas discharge in the chamber accelerates polymerization and rapidly initiates the Malter emission.
- Dielectric coatings (e.g. silicone lacquer) results in prompt initiation of the Malter emission; in this case, the observed cyclical character of the time dependence of the current can be attributed to the accumulation of the positive ion charge on the film surface, followed by its discharge.
- Vacuum oil on the cathode wire surface does not provoke the Malter emission until the collected charge of 190 mC/cm.
- Fingerprints on the cathode wire surface give rise to the Malter emission at 130 mC/cm.
- The Malter emission was not observed on the wire with deposited aluminum coating until the collected charge reached a value of 225 mC/cm, which is evidence that gold coating defects on the aluminum wire do not affect the Malter emission threshold at irradiation doses smaller than this value.
- The stepwise change in the Malter current indicates the discrete character of the Malter emission sources. In this case the current kicks are associated with the Malter emission disappearance and occurrence on isolated tips. In addition, being initiated at one point, the process becomes self-maintaining and propagates along the wire with a characteristic speed of 0.3 cm/s.
- The measurements of the autoemission threshold for the gold-plated aluminum and titanium cathode wires from different manufacturers has shown that all the wire samples exhibit close values of the threshold electric field strength, which are in the range of 65-67 kV/cm.

Acknowledgements

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References

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