Central Drift Chamber straw radiation test results

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This note describes a radiation test done with a prototype of the GlueX Central Drift Chamber. The goal is to determine if the aluminum anode layer inside the straw would be damaged by radiation expected in GlueX.

1 Introduction

The straw types that are a candidate to be used for the GlueX Central Drift Chamber (CDC) [1] all have an aluminum anode layer inside. There is a concern that this layer might get damaged after receiving a certain radiation dose, therefore it was decided to set up a radiation test.

2 Prototype

There are 4 straw types that might be used in the CDC: a kapton straw with a <1 μm Al foil inside produced by Stone (referred to as Stone-kapton), a mylar straw with Al foil (thickness is unknown) inside produced by Euclid (referred to as Euclid-mylar), and two mylar straws produced by Lamina, one with 300 Angstrom deposited Al inside (referred to as Lamina-thin) and one with a 15 μm thick Al foil on the inside (referred to as Lamina-thick).

For the radiation test a 30 cm long prototype was made that contained all 4 straw types. The prototype was fully operational and could be read out if desired.

A picture of this prototype after irradiation (some pieces of straw are cut out) can be seen in Fig. 1. The prototype was made and tested (for normal operation) at Carnegie Mellon University (CMU). It was then transported to Jefferson Lab for irradiation and brought back to CMU for follow-up testing.

Figure 1: Picture of a four straw prototype after radiation and examining of the straws.

3 Radiation Dose

The source used for irradiation was a $3.7 \cdot 10^{10}$ Bq ^{90}Sr source. The source was collimated and a length of about 1 cm of the straw was irradiated. The received doses per straw are shown in table 1. All the doses are well below 1 C/cm which can rule out traditional aging effects of the straws. The received doses are equivalent to about 44 or more years of running in the GlueX experiment. The straws were irradiated when high voltage was applied.

Straw type	Received dose [C/cm]
Stone-kapton	0.009
Euclid-mylar	0.004
Lamina-thin	0.010
Lamina-thick	0.004

Table 1: Received doses of the irradiated straws.

4 ^{55}Fe Results

In Fig. 2 the gain of the straw is shown as a function of distance from the read out electronics. The gain is measured using an ^{55}Fe source. The red point indicates the spot where the straw was irradiated. In general one expects a slowly decreasing gain as a function of distance from the read out electronics followed by a more drastic drop if one gets close to the end of the straw (the electric field lines get distorted due to the presence of material that holds the straw). This behavior is observed in all the straws except in two points: at 7 cm distance there is a dip in the Stone-kapton and the Lamina-thin straw. The dip in the Stone-kapton straw might be due to the irradiation. Although the Lamina-thin straw was located under the source as well during irradiation, it is not clear if the dip is also due to radiation because the other way around there is no dip in the gain observed for the Stone-kapton straw where the Lamina-thin straw got irradiated (at 24 cm distance). It also seems that the Lamina-thick straw got irradiated quite close to the end where you expect to see a drop in gain due to electrostatic effects.

5 Visual inspection

After irradiation and the ^{55}Fe measurements, the straws were cut open to visually inspect them. The area that was irradiated was compared with an area that was not irradiated and a straw that was never used. The results are shown in Fig. 3. First of all, all Al layers seem to be intact and no cracks were observed. Although one cannot see differences between irradiated areas and not irradiated areas, there is a clear difference between the straw that was not used and the straw that was irradiated for the Stone-kapton and Lamina-thick type straws. It seems that something got deposited on/etched the aluminum layer, the questions is what it and what caused it. The same thing probably happened for the other two straw types but due to different finish it cannot be seen with the naked eye.

6 Inspection with an electron microscope

The Material Science department at Carnegie Mellon University has electron microscopes which we can use. Several pieces of irradiated and not irradiated straws were inspected using this microscope.

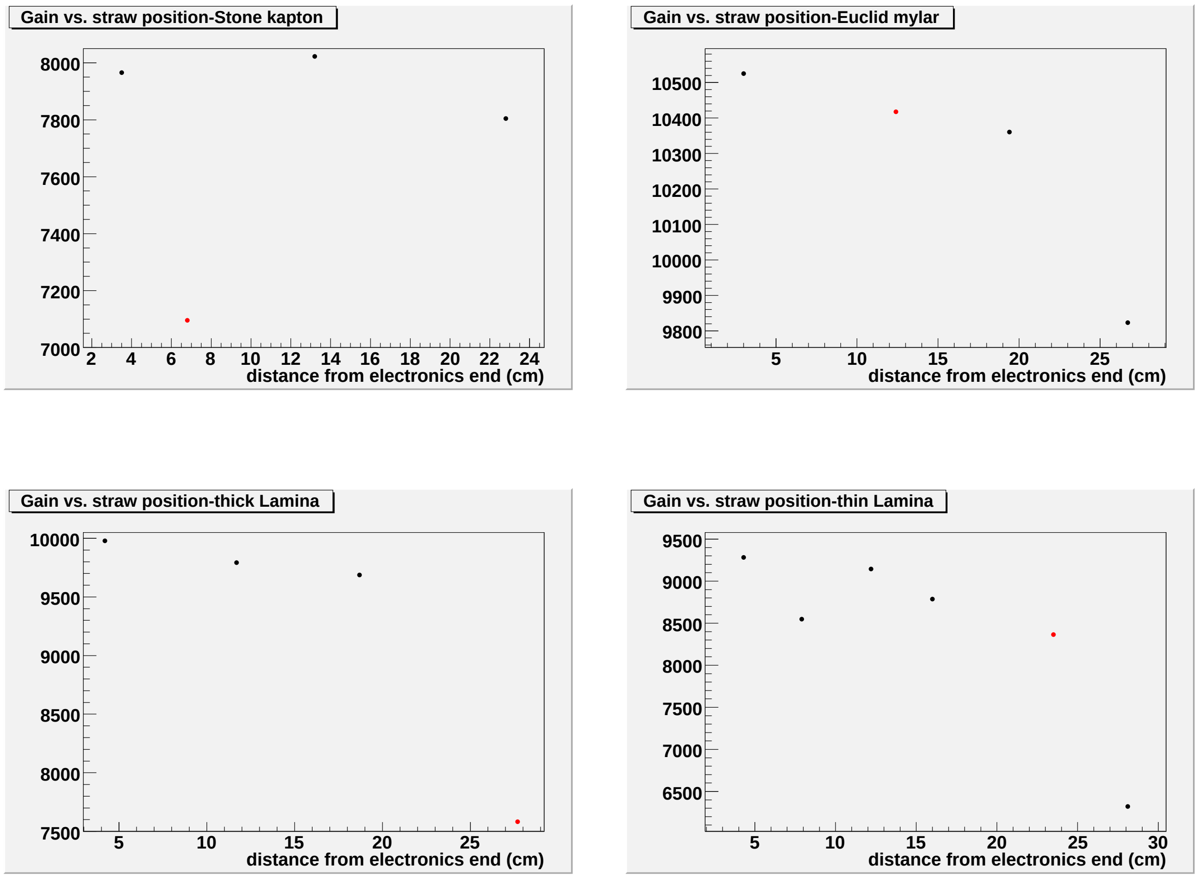

Figure 2: Gain as a function of distance from the readout electronics for the four tested straws. The red point indicates where the straw was irradiated.

6.1 Lamina-thick

A piece of Lamina-thick straw that was never used was compared with a piece that was irradiated. A comparison at the lowest scale can be seen in Fig. 4. On this scale one can see black impurity lines on both straw pieces, probably due to the fabrication. A difference that can easily be seen is the dark gray areas on the irradiated straw which are not visible on the straw that was never used. When zoomed in one can clearly see in Fig. 5 that the irradiated straw shows a lot of black pits and that the dark gray areas in Fig. 4 are a different size and concentrations of those black pits. What caused those pits remains a question.

6.2 Lamina-thin

A piece of Lamina-thin straw that was never used was compared with a piece that was irradiated. A comparison at the lowest scale can be seen in Fig. 6. Both straws look very smooth compared to the same pictures taken of the Lamina-thick straw. On this scale one can see that there is no real difference between the two. Also if zoomed in (Fig. **??**) no real difference can be seen. The white dots are Fe traces, how they got there is not known but probably it got there during fabrication. The fact that this straw did not show any difference makes it a good choice to be used in the final detector setup. The difference with previous straw (Lamina-thick) is, according to the manufacturer, that the aluminum is deposited on the mylar instead of glued. It might be that glue that caused the black pits on previous straw.

6.3 Gold plated tungsten wire

In Fig. **??** a new wire is compared with an irradiated one on different scales. No difference can be observed.

7 Conclusion

Four different types of straws were irradiated to test for cracks in the inside aluminum anode layer. After receiving a dose that is equal or more than 44 years of running but not high enough to cause common aging effects, no effects on the aluminum anode layer were observed. When the irradiated straws were compared with straws that were not used using an electron microscope differences were observed. The irradiated Lamina-thick straw showed pits in the aluminum layer. How those pits are caused remains a question but it might be caused by the glue used to glue the aluminum to the mylar. The Lamina-thin straw did not show any differences between the not used and the radiated straw. Therefore this straw will be used for the final detector setup. The wire was also investigated using the electron microscope. There was no difference observed between a radiated part and a wire-part that was never used.

8 Acknowledgement

Thanks to Ryan Booth from Carnegie Mellon University for taking the electron microscope pictures and help to understand them.

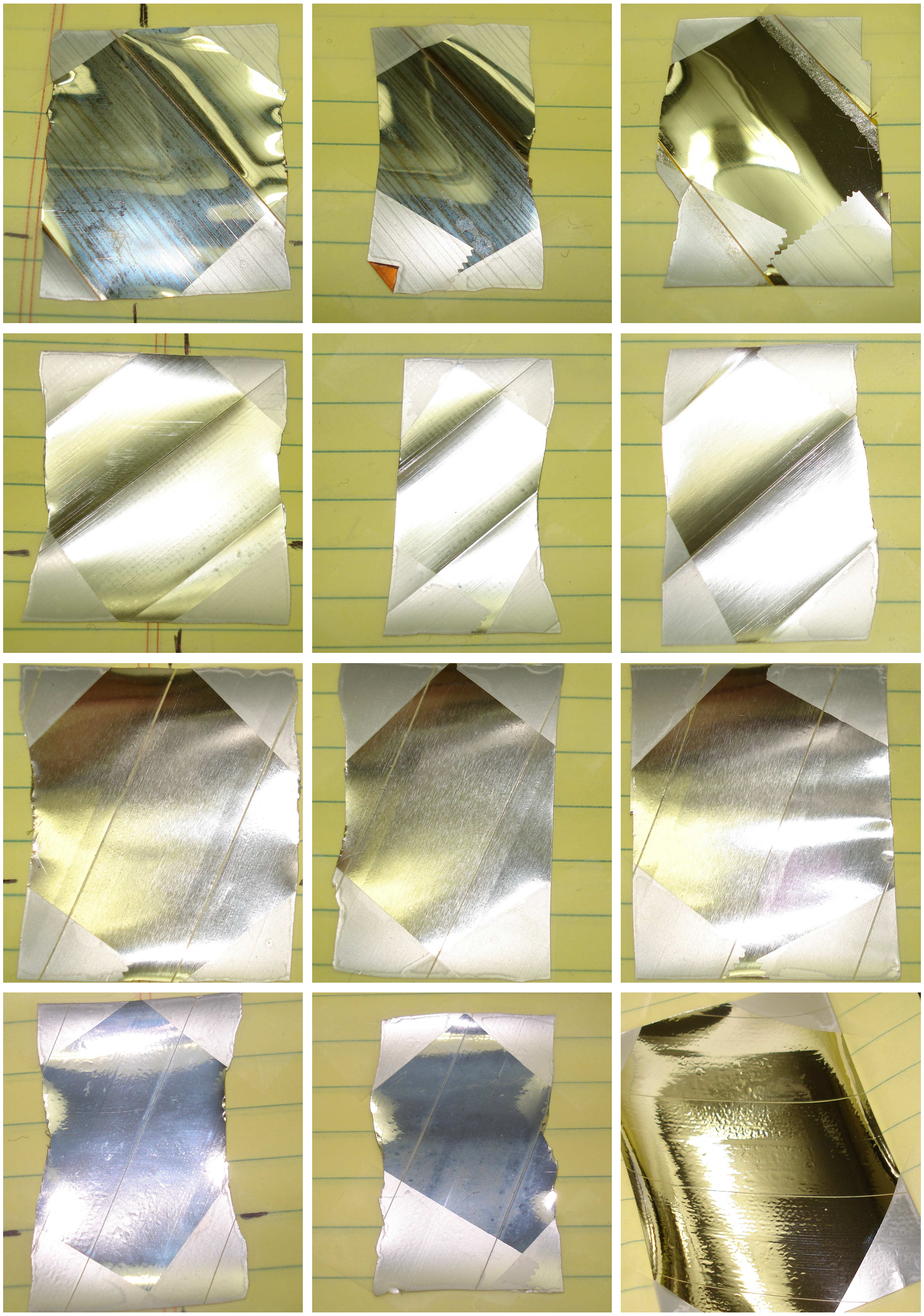

Figure 3: Pictures of the straws that were visually inspected. From left to right: area of the straw that was irradiated, area of the straw that was not irradiated, and area of the same type of straw that was never used. From top to bottom: Stone-kapton, Euclid-mylar, Lamina-thick, and Lamina-thin straw.

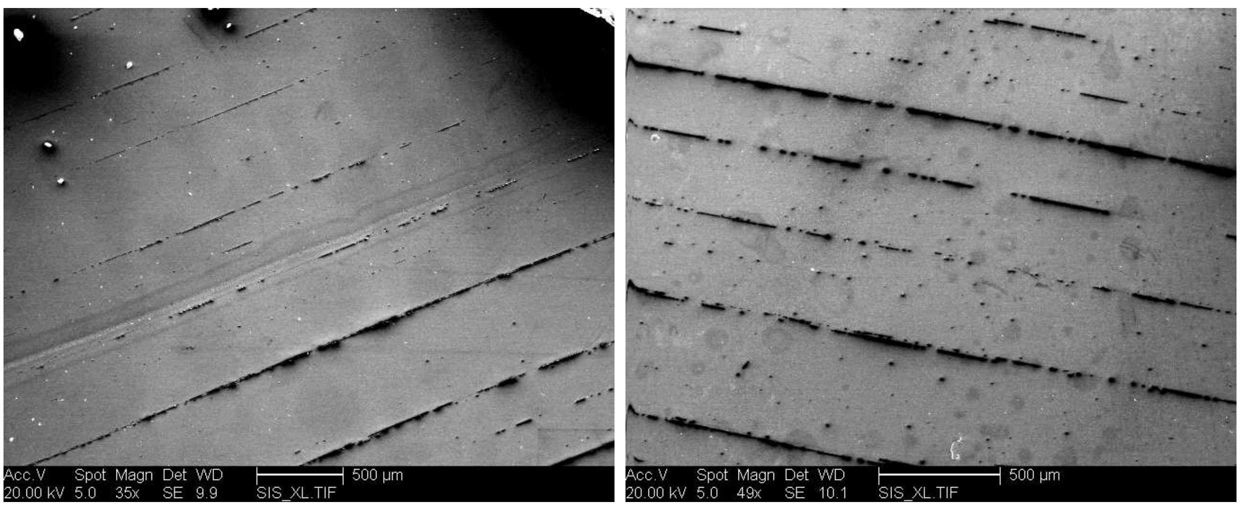

Figure 4: Comparison between a Lamina-thick straw that was not used (left) and the one that was irradiated (right) at 500μm scale.

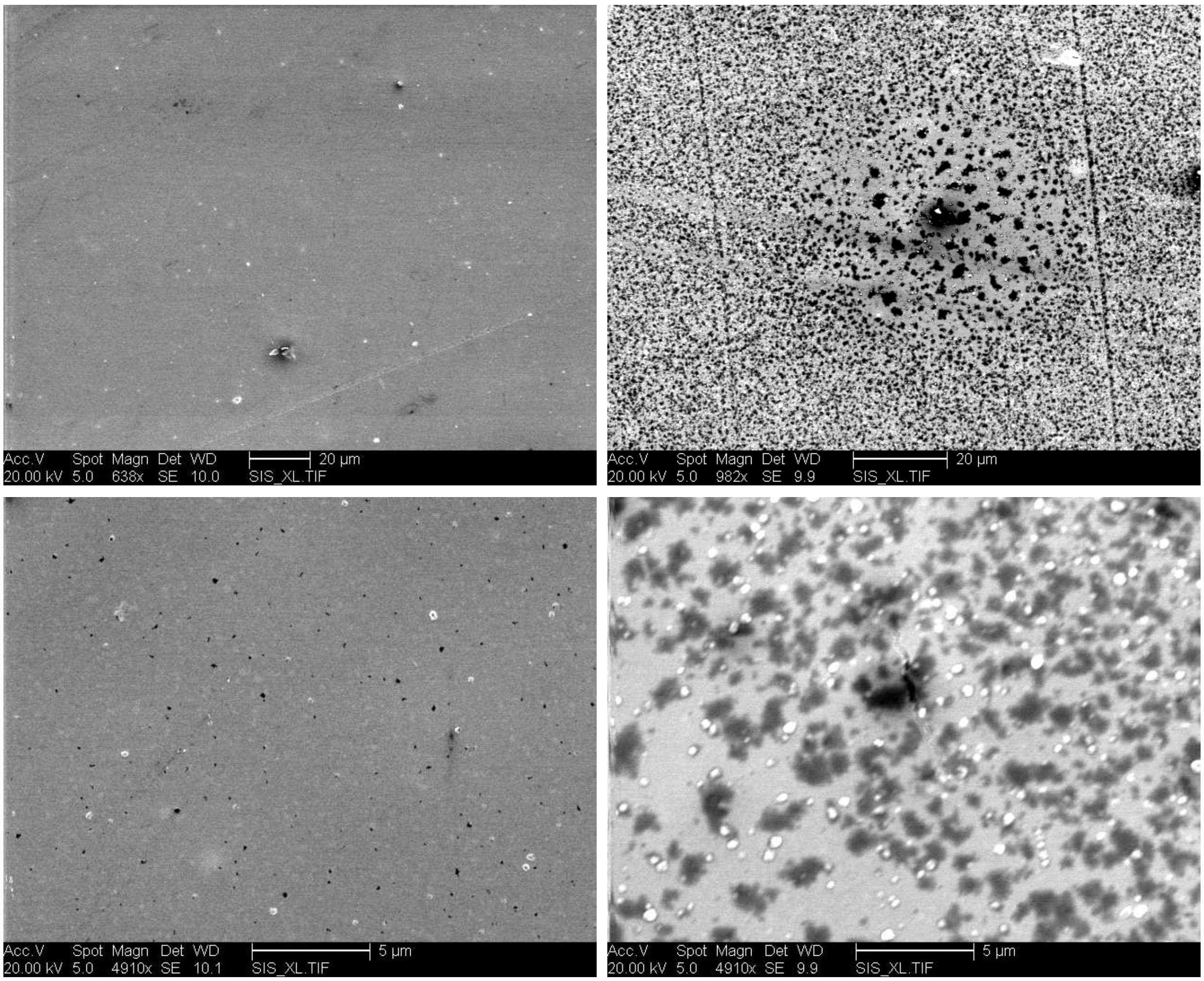

Figure 5: Comparison between a Lamina-thick straw that was not used (left) and the one that was irradiated (right) at 5 and 20μm scale.

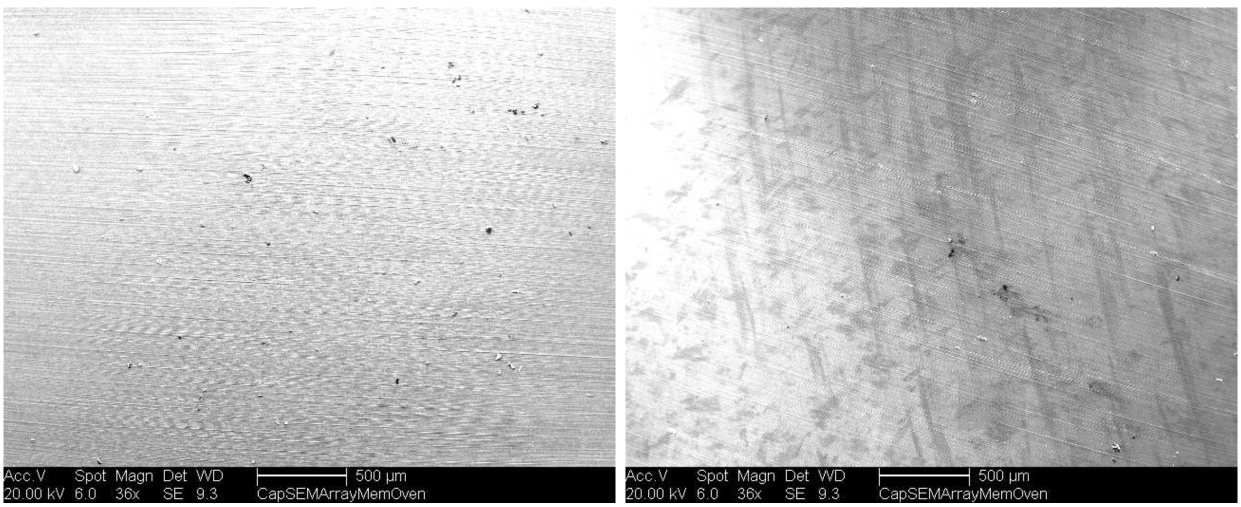

Figure 6: Comparison between a Lamina-thin straw that was not used (left) and the one that was irradiated (right) at 500μm scale.

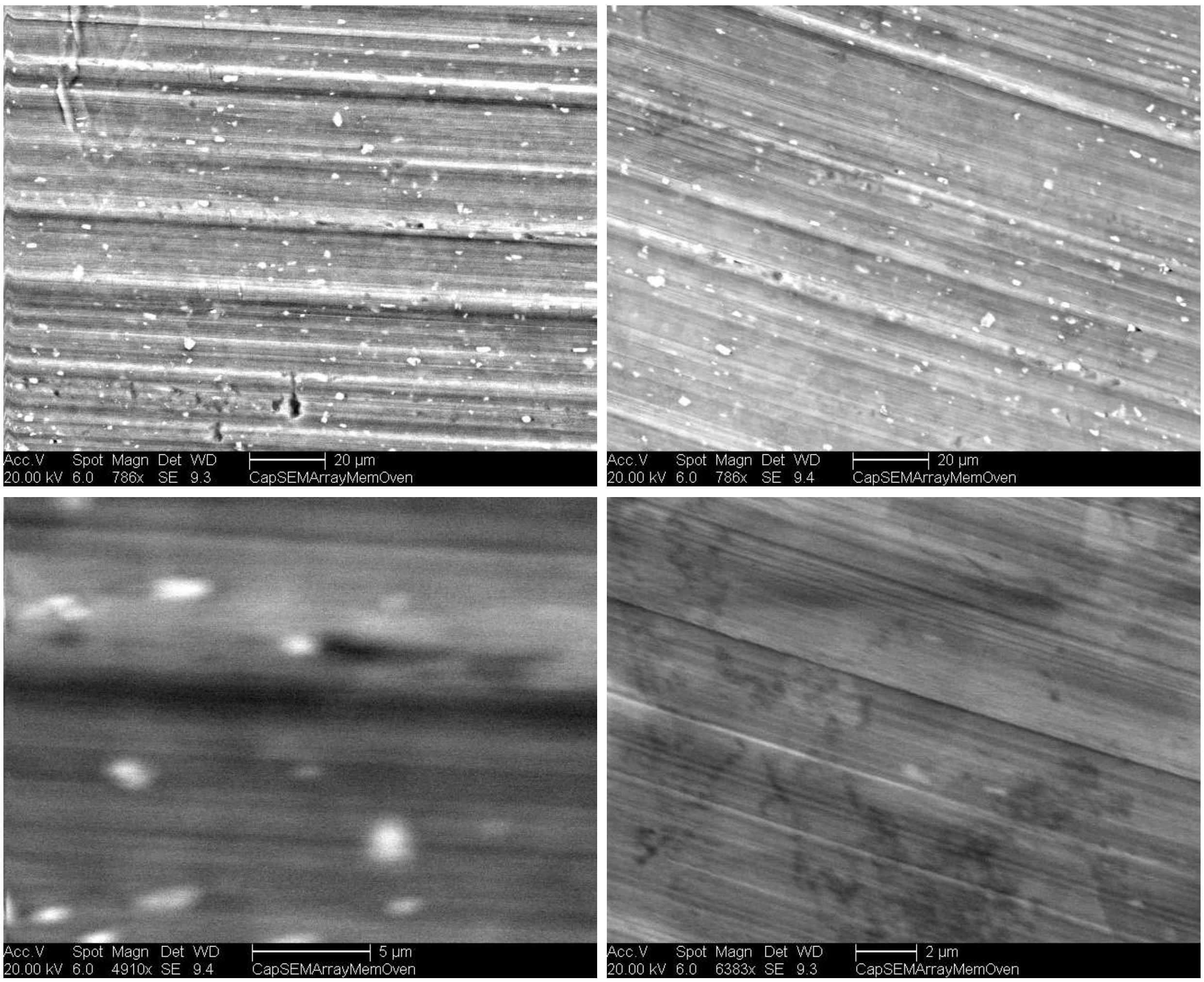

Figure 7: Comparison between a Lamina-thin straw that was not used (left) and the one that was irradiated (right) at 5 and 20μm scale.

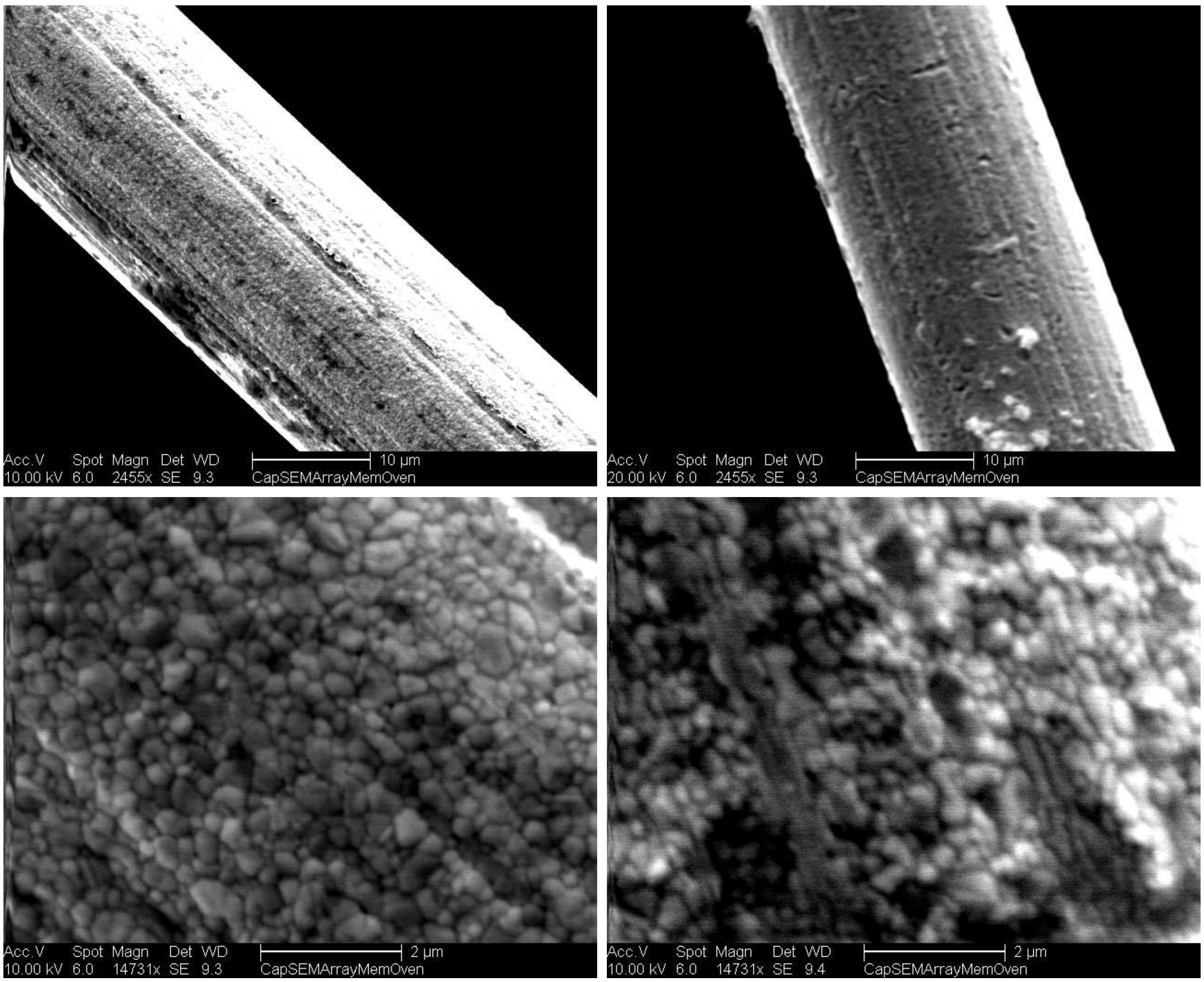

Figure 8: Comparison between a wire that was not used (left) and one that was irradiated (right) at 2 and 10μm scale).

References

[1] Curtis A. Meyer and Yves Van Haarlem, **The GlueX Central Drift Chamber**, GlueX Document 990, March 2008.