Total grinding time took approximately 40-180 minutes in our case. After such grinding almost no defects were observed with 100-magnifying microscope in the capillary inner edge. Finally the capillary tip was finished with Fe_2O_3 polishing using polishing pad. This takes only 1-2 minutes, because longer machining time leads to sharp edge rounding.

We wanted to measure the quality and radius of machined capillary edge, but it showed to be a problem to find an appropriate instrument for it. This problem was limited by capillary inner diameter 0.32 mm, the edge angle of 90°, the capillary length 35 mm and its fragility. Optical methods like confocal microscopes or optical profilometers have sufficient 3D resolution, but they are limited to measurement of surfaces with slope usually less than 30° only. We tried to use an atomic force microscope (AFM) PSIA XE-100 equipped with high aspect ratio in contact-less mode. This measurement shows very good capillary face quality with roughness Ra = 0.6 nm, Rz = 2.7 nm on clear tip surface of dimensions 5x5 µm. It enable us to measure the edge profile too as it is shown in the figure 6.

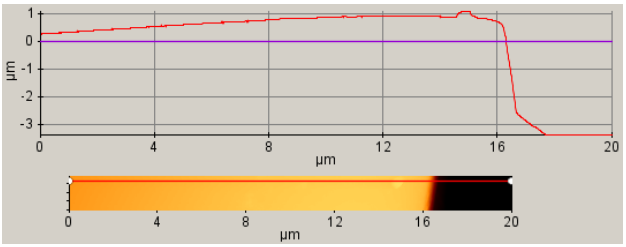

Fig. 6. The capillary inner edge profile in AFM.

We found out the edge radius changes along the edge but it was measured within the range 100-450 nm within observed area. AFM microscope enables us to measure only parts of the capillary edge, because of its work range limits 100 µm in X, Y-axis, Z-axis range 25 µm. The best way how to check the whole capillary edge or its details gave us a scanning electron microscope (SEM) only. It confirmed very good capillary edge quality, as it is shown in the figure 7.

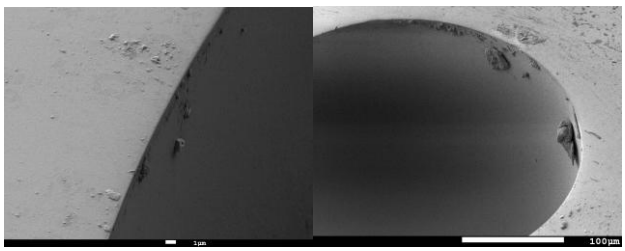

Fig. 7. Detail of the capillary inner edge in SEM.

5 Conclusions

Our results demonstrate possibility to achieve very sharp edges down to 100 nm radius on the brittle material as a fused silica capillary using classical optical grinding and polishing technology. Machine conditions, which allow achieving of sharp edges on brittle material, involve fine grinding with gradually or sequentially decreasing of in-feed load during the grinding and finishing polishing. This method, unfortunately, implies much longer working time then in the case of classical production grinding and still does not eliminate edge chipping on brittle material completely. We observed capillary edge chipping up to 3 µm radial dimensions within grinding period, which were finally smooth down by polishing process. Our experiments in liquid sample surface tension measurement using Ferguson method shows that such capillary chipping is acceptable for this measurement.

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