BEMills 20150429 The book title is "A Million Hours of Service". Author is Tom Bramell

Images for possible inclusion in book on Livermore Light Bulb

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Optical image of filament with 35x lens

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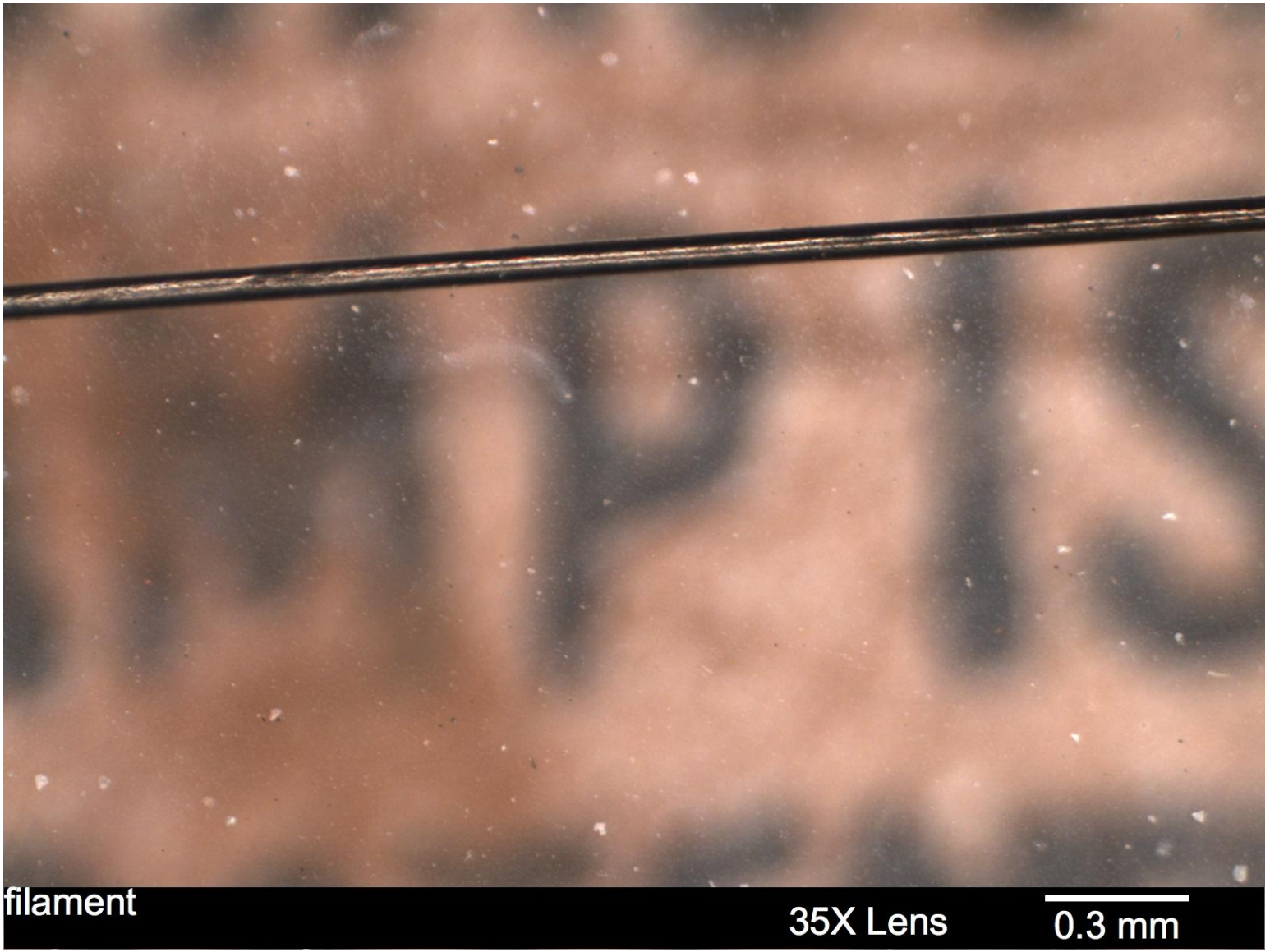

Optical image of paper folded and sealed in glass inside lamp. Top image was the only one visible without breaking glass.

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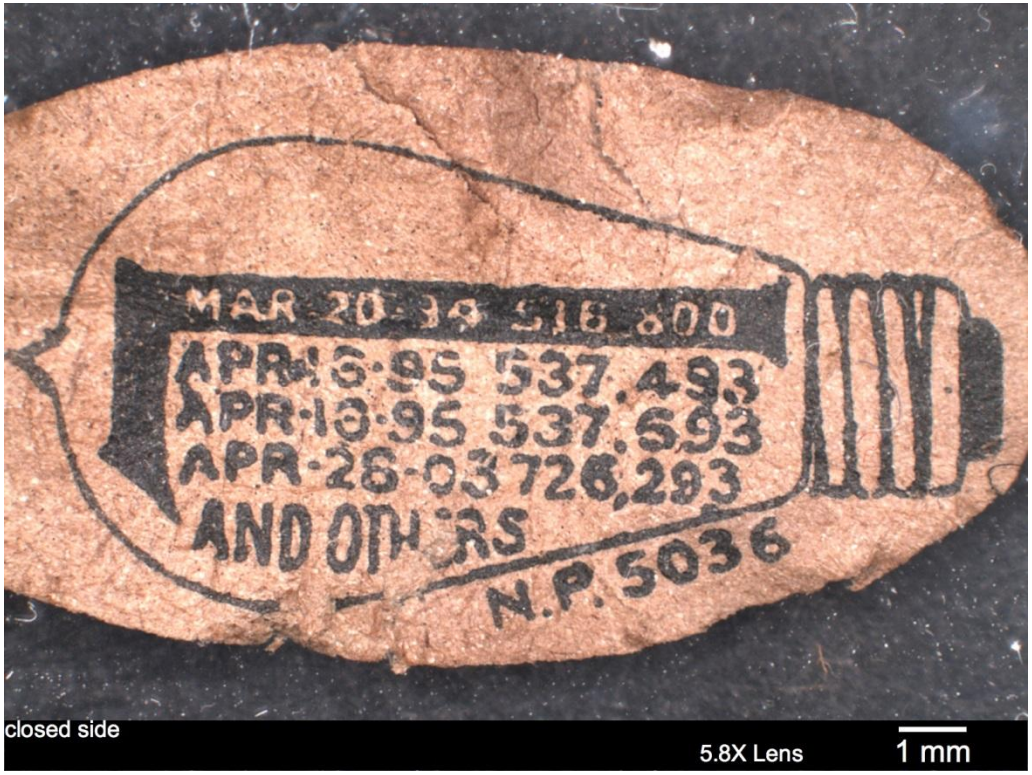
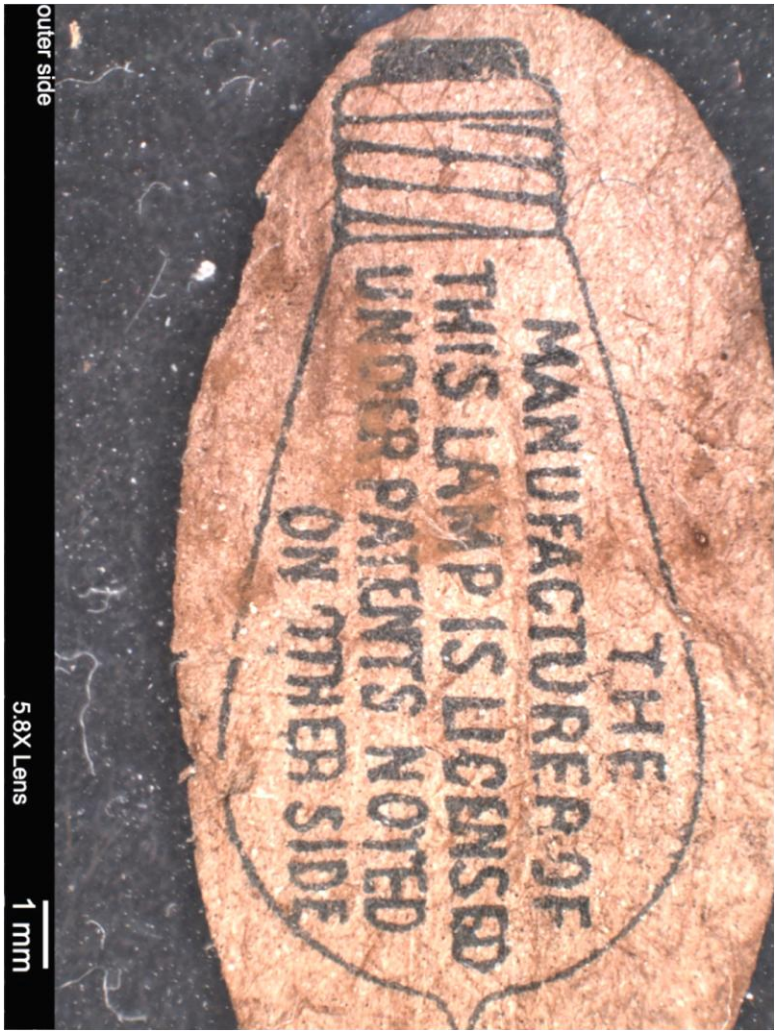
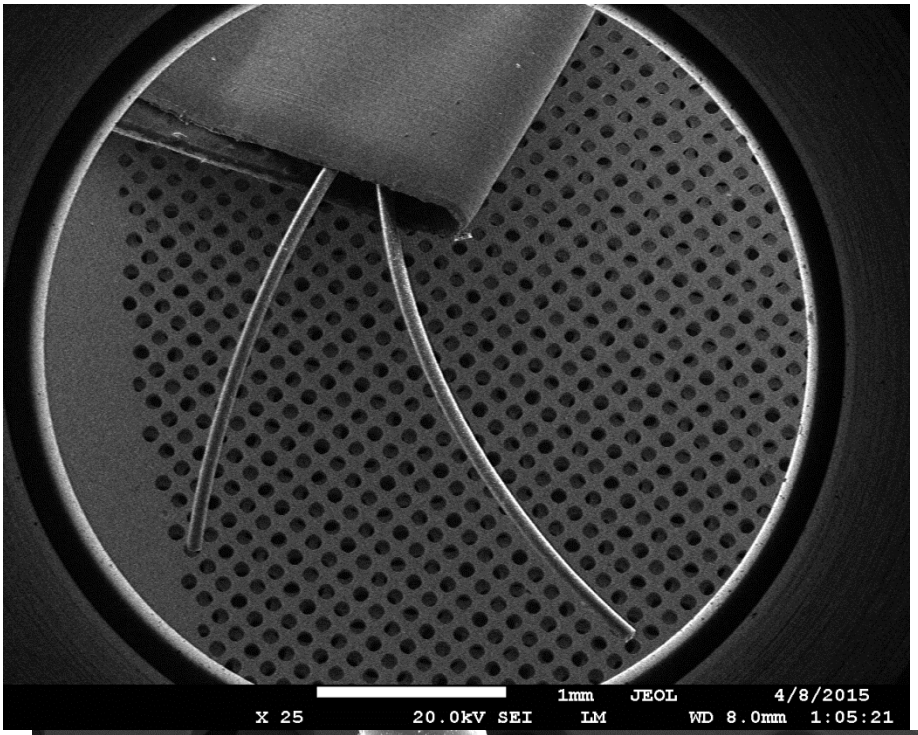
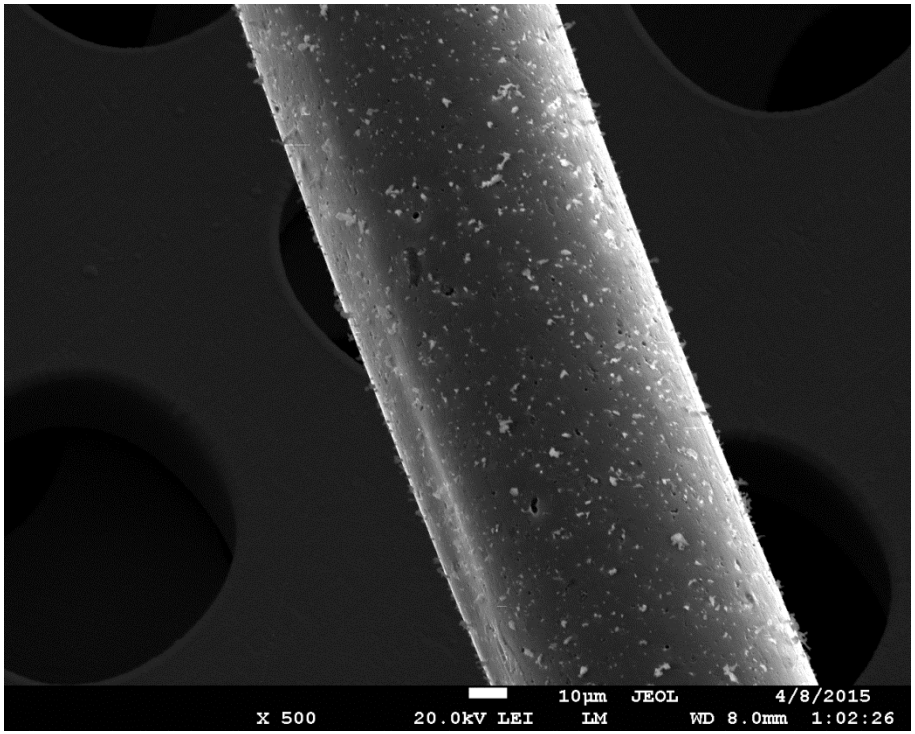
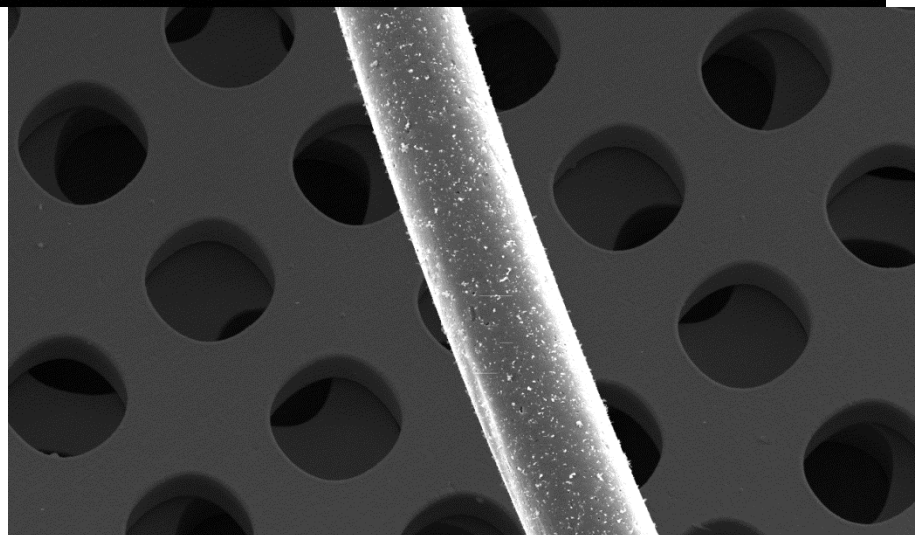


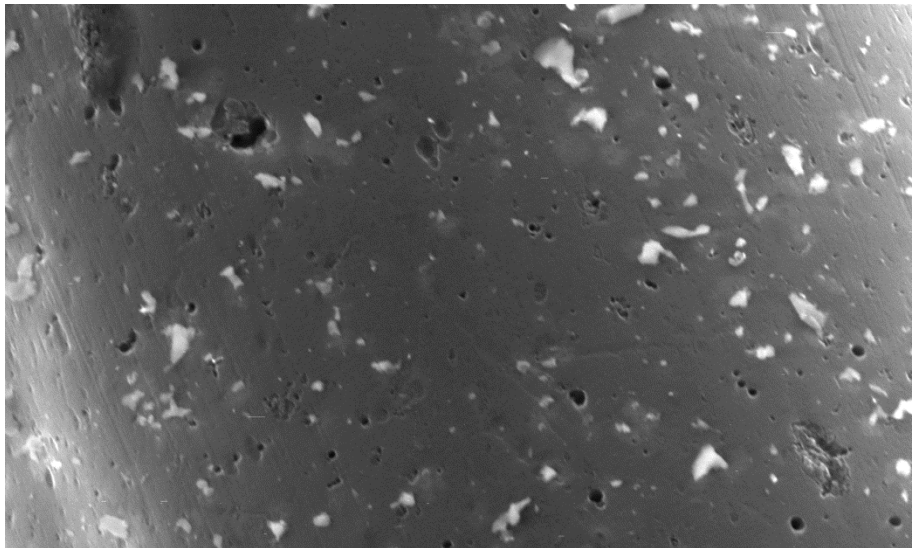


Secondary electron images of filament at 52x, 200x, 500x, 2000x. Analysis by x-ray spectroscopy, which samples microns deep, indicates the filament is carbon. Some of the white flecks are silica, presumably from the glass.









Lamp at two orthogonal orientations in x-ray microscope. X-ray source to left, camera to right.

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X-ray of old bulb at left compared with new bulb at right shows that the filament cannot be seen through the glass and therefor must be of low atomic number..

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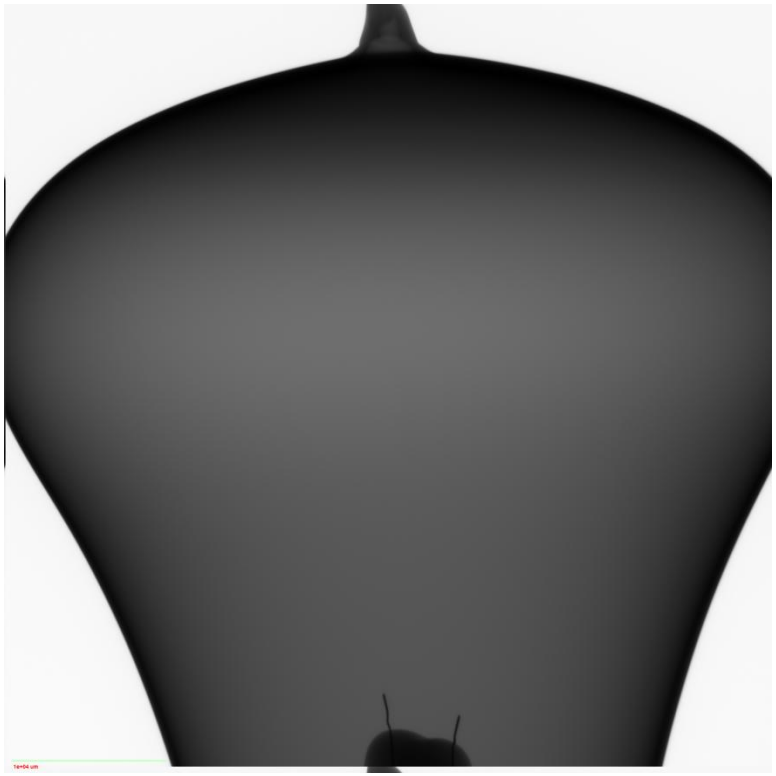

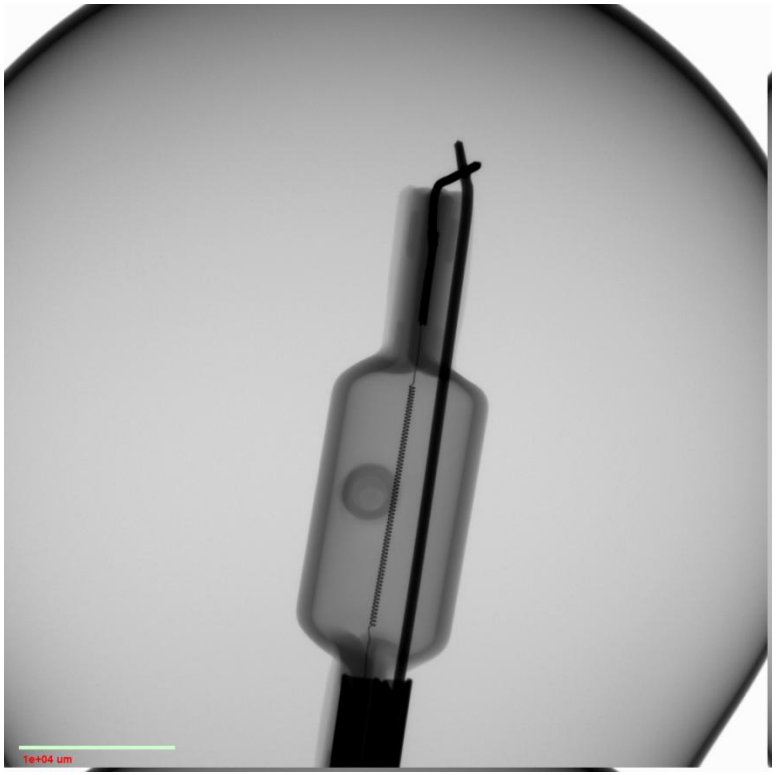

The pin to which the filament is attached is easily seen through the glass. The attachment material is not seen.

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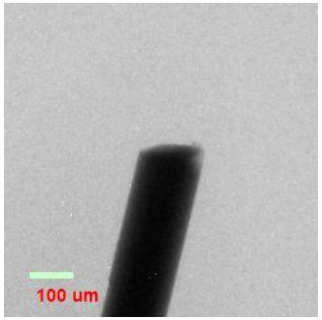

The loops of the filament are seen in an x-ray image. A close-up image allows us to measure the diameter of the filament. The white edge that is seen is the image is from phase contrast.

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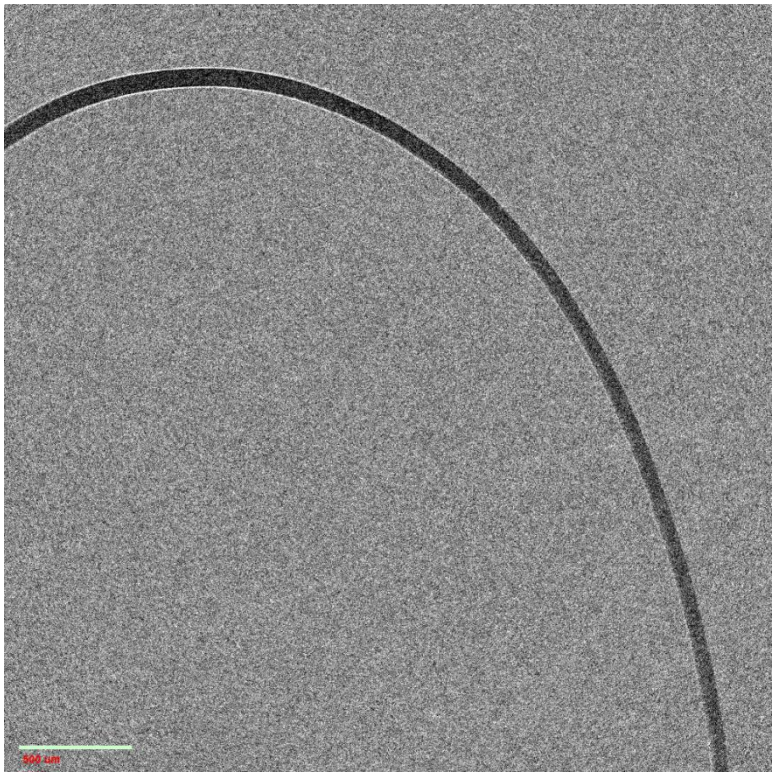

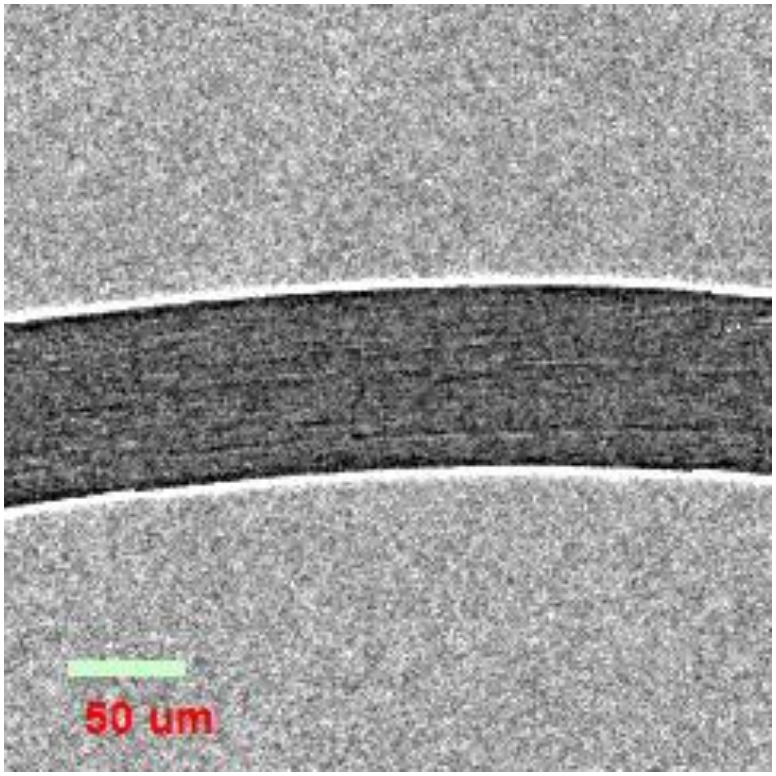

A section of the filament is seen in this three dimensional x-ray image.

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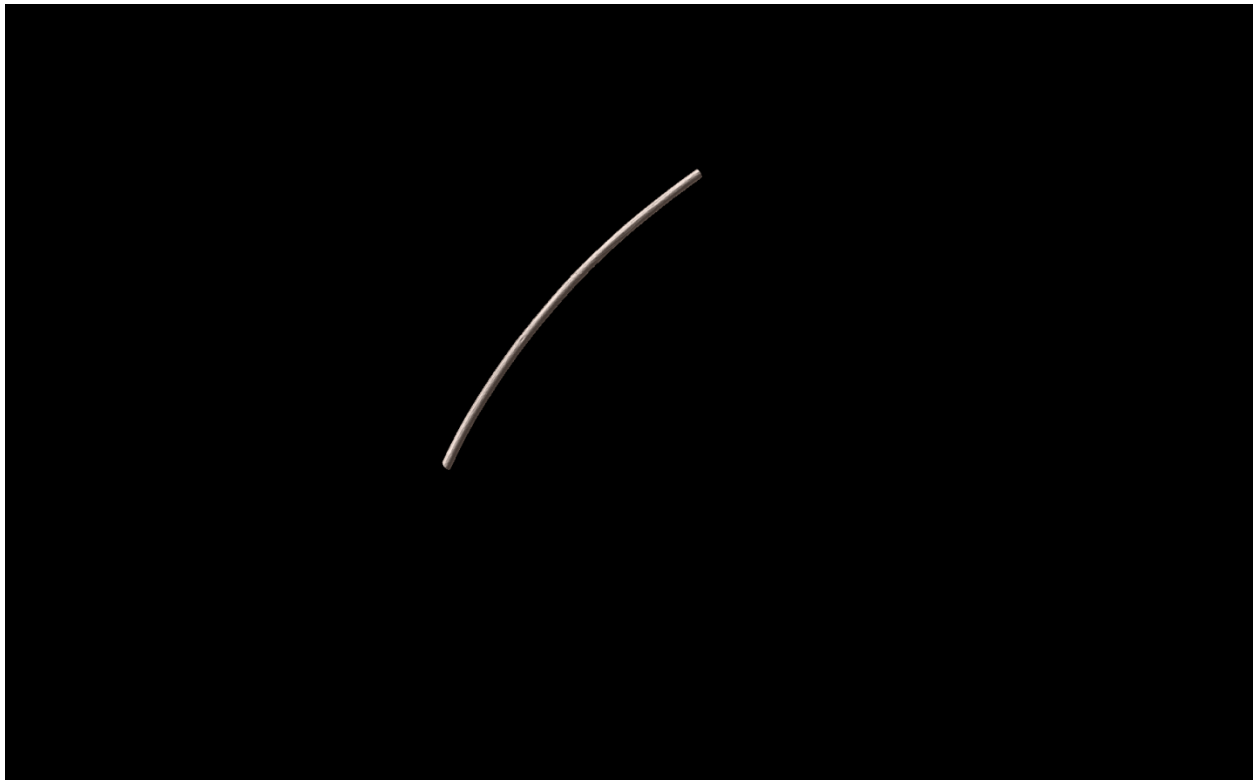

The filament is distinctly round as seen in these three dimensional x-ray images of a section of filament. The lower image highlights the surface texture of the filament.

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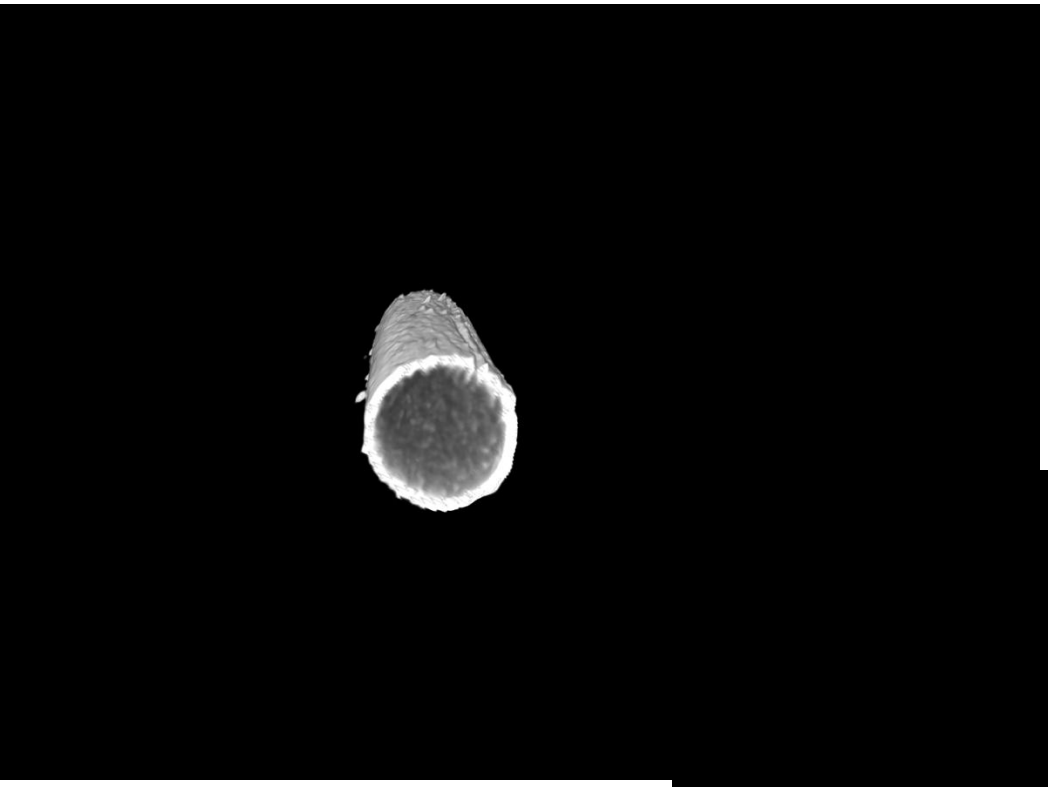

Auger spectroscopy, which only samples nanometers of the surface, shows the filament to be carbon. This precludes the filament having been plated with some metal.

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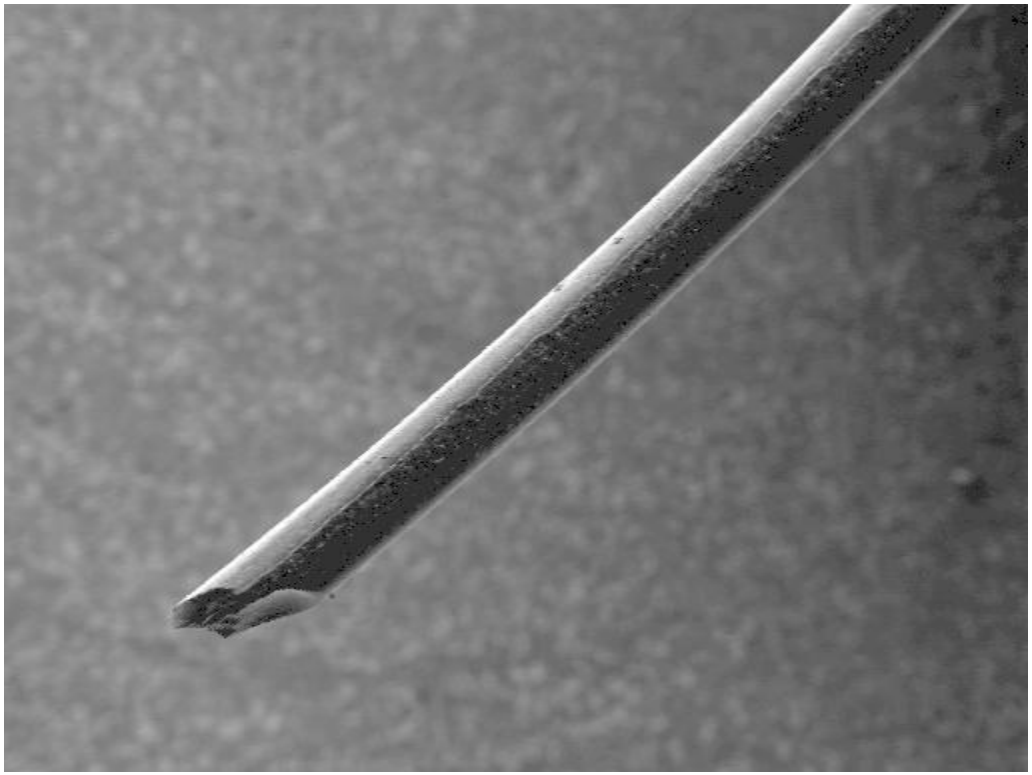

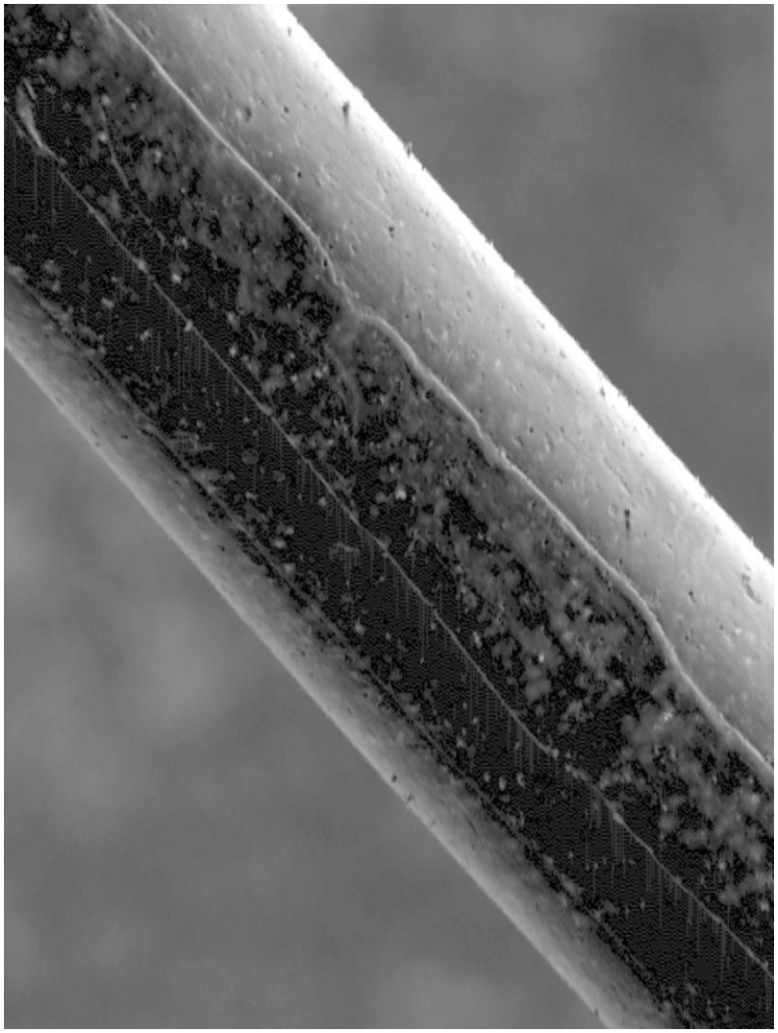

Participants and conclusions:

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Howard A. Johnsen mounted the lamp for further work.

Jeff M. Chames broke the outer and inner glass envelope and produced optical and secondary electron images of the filament and the paper with the patent numbers. He also took x-ray spectra to demonstrate that the filament was made of the carbon with small flecks of silica on the surface.

Dr. Bernice E. Mills performed the x-ray computed tomography both before and after the outer glass was removed to show that the filament could not be seen through the glass envelope and to show that the filament is round with a diameter of about 80 microns or 3 mils and with small bits of debris on the surface. She also analyzed the surface of the filament with Auger spectroscopy to confirm that even the surface is carbon and cannot have been plated.