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FABRICATION OF TUNGSTEN WIRE NEEDLES*

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Fine point needles for field emission are conventionally produced by electrolytically or chemically etching tungsten wire. Points formed in this manner have a typical tip radius of about 0.5 microns and a cone angle of some 30 degrees. The construction of needle matrix detector chambers has created a need for tungsten needles whose specifications are: 20 mil tungsten wire, 1.5 inch total length, 3 mm-long taper (resulting in a cone angle of about 5 degrees), and 25 micron-radius point (similar to that found on sewing needles).

In the process described here for producing such needles, tungsten wire, immersed in a NaOH solution and in the presence of an electrode, is connected first to an AC voltage and then to a DC supply, to form a taper and a point on the end of the wire immersed in the solution.

The process parameters described here are for needles that will meet the above specifications. Possible variations will be discussed under each appropriate heading.

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Materials

Wire - Needle points can be formed equally well on pure and thoriated tungsten, except that the quality of the polish on thoriated material is not as good as the one obtained on pure tungsten. Both fully annealed and hard wire can be used; annealed wire was used in this instance because hard, brittle wire (welding electrodes) can shatter when electrical connections are crimped onto it. Every attempt should be made to cut the wire cleanly and perpendicular to its axis, thereby ensuring that the formed point is centered; bevels and ragged edges will be reflected in a poor position and quality of the point.

Solution - 1N NaOH (44 grams of sodium hydroxide per liter of water) provides a good compromise between the rapid etching rate, and tendency to form pits, of more concentrated solutions, and the unnecessary slower cutting rate of more dilute solutions.

Electrode - The electrode immersed in the NaOH solution consists of a loop of tungsten wire, 3/4 inch in diameter, formed on the end of a 10-inch length of the same wire, and bent at a right angle to it. Experience has shown that the taper of the needle is determined by the shape of the electric field created by the loop electrode; it is therefore important that the loop be as distant as possible from the wire being processed, and that the wire supporting the loop be insulated from the solution. The latter is achieved with a coating of masking paint, in this case P Dapcoat 1001, manufactured by Organoceramics of Santa Anna, California, and available at the SLAC Plating Shop. A relatively simple coating method is to dip the full length of the wire support into a tube containing the paint, and allow it to dry in air. During the AC processing phase, the electrode is etched at the same time as the wire and eventually has to be replaced when the loop becomes detached from its support. Spares should be prepared ahead of time, allowing the masking paint to dry before immersion in the solution.

Equipment

Etching and polishing are performed in a glass cylinder, 25 mm in diameter and 250 mm high (Pyrex culture tube), filled with 1N NaOH to about one inch from the top; the unfilled portion of the tube helps confine the spattering of the etching reaction. The electrode is inserted into the tube with the loop as far away from the top as possible; the masking paint is stripped away from the free end of the support wire, which is then bent over the edge of the tube to maintain the electrode in place.

The wire on which the needle is to be formed is held in a clamp (hemostat or equivalent tool); since the length of the tapered portion of the needle point is determined by the depth to which the wire is immersed, it must be possible to move the clamp and wire vertically with a precision of one thousandth of an inch. A microscope rack-and-pinion slide was selected in our case, along with a machinist's dial gauge to indicate the depth of immersion.

Power supplies with ranges of 0-25 VAC and 0-5 VDC, and current capabilities of no more than 100 ma, are connected to the clamp and the electrode wire; because the sharpness of the needle point is determined by the duration of the AC etching step, and the degree of polish by the

duration of DC polishing step, both power supplies are plugged into a timer with a resolution of one second and a range of 0-10 minutes, a Gralab laboratory timer in this instance.

Method

Wire cut to the desired length is clamped in place, slowly lowered until it comes in contact with the solution, and then immersed to the desired depth. Experience has shown that a tapered length of 110 mils requires an immersion of 70 mils; the difference between these two figures takes into account the etching that occurs at the meniscus formed around the wire. The height of this meniscus is determined by the intensity of the etching reaction.

As the AC voltage is turned on, gas bubbles begin to form at the electrode and at the wire, eventually permeating the solution as the reaction proceeds. The absence of gas evolution is an indication that the electrode has been destroyed and needs to be replaced. The density of the bubbles is determined by the etching rate, which in turn depends on voltage; the value of 10 volts selected in our case proved to be sufficiently high to limit the necessary etching time to 4 minutes. Lower voltages reduce the etching rate without significantly improving reproducibility, while making the reaction time unnecessarily long; higher voltages increase the violence of the reaction without appreciably reducing the time required for etching. At 10 volts, a difference of 30 seconds in etching time results in points whose radius is visibly different at a magnification of 30X.

With the wire connected to the positive terminal of the supply, and the electrode negative, the DC voltage is turned on as soon as the AC etching step has ended. The value of this voltage is the one at which no significant increase in current can be detected as the voltage is raised, in this instance 3 volts. Polishing is rapid but removes very little metal; no further improvement in surface finish could be observed after one minute of processing.

When the polishing step has ended, the wire is withdrawn from the solution, rinsed with water, and allowed to dry. The needle is then ready for use. The reproducibility of the process is estimated to be five microns in the radius of the point, and about two mils in the length of the taper.