Transformation of polycrystalline tungsten to monocrystalline tungsten W(100) and its potential application in Schottky emitters

A.K.Dokania and P.Kruit
Faculty of Applied Sciences, Delft University of Technology, Lorentzweg 1, Delft 2628 CJ, The Netherlands.
Phone: +31-152781516, e-mail: a.k.dokania@tudelft.nl

The Schottky emitter is known for its high brightness and high current stability and would be the ideal electron source for a parallel electron lithography system. The current method of preparation of Schottky emitters involve electrochemical etching of W(100) wire, however W(100) is not easily available in all desired dimensions needed for large arrays. In a paper by Okuyama[1], the author described the transformation of polycrystalline tungsten to W(100) by a complex heating process involving carburizing and decarburizing the tungsten tip. The crystallographic transformation of polycrystalline tungsten to W(100) by DC Joule heating is observed in welding arc electrodes[2]. In this paper an attempt is made to utilize this phenomenon for the fabrication of Schottky emitters.

We are investigating the possibility of creating an array of Schottky emitters of 1mm diameter at the pitch of 1.5mm for a parallel electron beam lithography system. We have reported[3] the fabrication of Schottky emitters of 1mm diameter of pure polycrystalline tungsten by Wire Electrical Discharge Machining (WEDM) also known as spark erosion, the schematic of which is shown in figure 1. Figure 2 shows several tips of such emitters, after DC Joule heating, depicting parallel grain structures. After the DC Joule heating, the crystallographic orientation of the sample is investigated by electron diffraction. To make the sample electron transparent for the electron diffraction experiment, the sample is thinned down by FIB, as shown in figure 3. The electron diffraction experiment was performed on Philips CM30UT electron microscope at 300KV and the result is shown in figure 4. The basic structure reflections of (200) and (020) are indicated by arrows which confirms the W[100] orientation along the emission direction. Normally after heating, W(110) is formed owing to its low surface free energy. However, during DC Joule heating, because of anisotropy in conductivity at higher temperature, the current density vector induces recrystallization in a direction which has least resistance. For BCC metals such as tungsten it is the [100] direction and for FCC, it is the [110] direction. In our sample the transformed W(100) in the heating filament must have acted as a seed crystal for the tip.

We will extend the same concept for our multi-beam source. The above method is cost effective and facilitates the use of WEDM technique for polycrystalline tungsten. It also opens up the possibility to fabricate monocrsytalline metal of [100] or [110] direction of any complex shape for other applications. The electron emission experiment of such a tip is underway.

[1]F. Okuyama Phys. Stat. Sol. (a) 55, 793(1979).
[2]V.F.Gordeev et al, Physics Chemistry and Mechanics of Surfaces 4(11), 3358-67 (1987).
[3]A.K.Dokania et al, presented at MNE 2007, Microelect. Eng. (accepted).

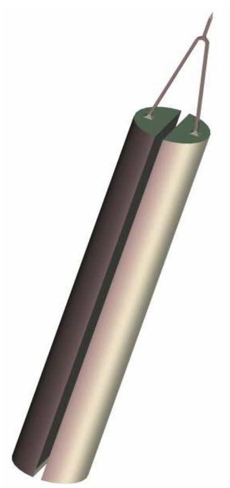

Fig 1. Schematic of 1mm Schottky emitter fabricated by WEDM.

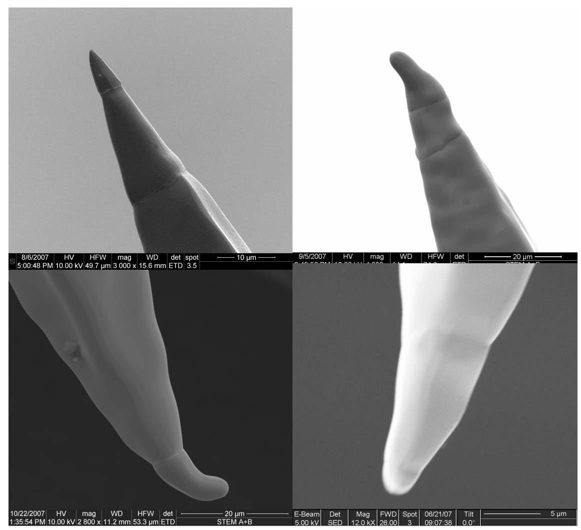

Fig 2. Morphology of different tips made by WEDM after DC heating.

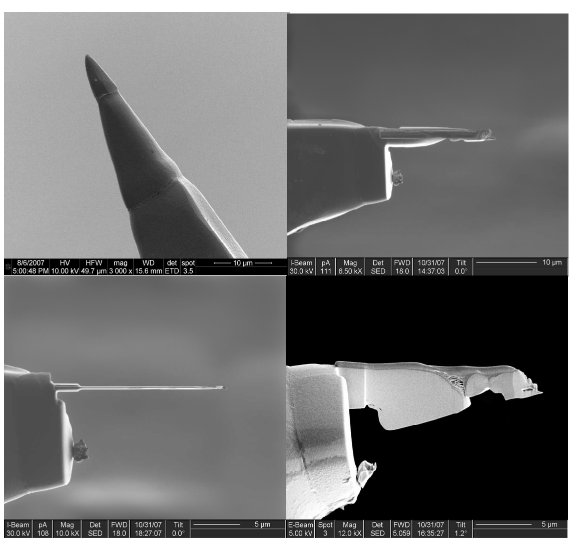

Fig 3. FIB milling of the WEDM sample for electron diffraction experiment.

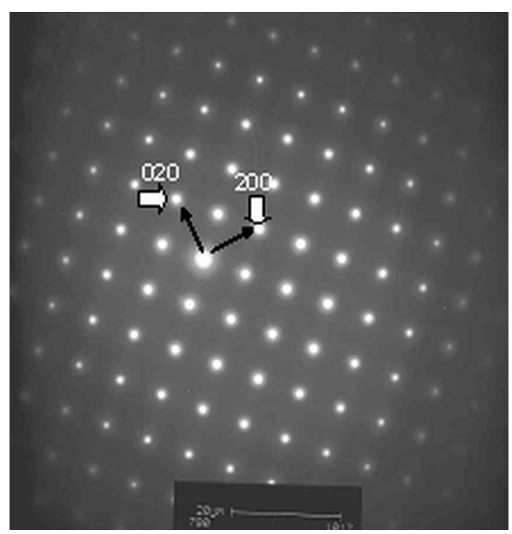

Fig 4. Electron diffraction pattern from the sample in Fig 3, confirming W(100) orientation.