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APPLICATIONS OF IMPROVED POINT CATHODE SOURCES TO HIGH RESOLUTION ELECTRON MICROSCOPY

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Extending earlier work (1-4) improved point cathode sources have been developed and used routinely in high resolution microscopes. Pointed filaments are made of etched, oriented single-crystal tungsten tips (ca. 100μ long; tip radii: 0.1-10μ) spot-welded on zone-refined tungsten wire. Because of high purity and selected crystal orientation, these filaments have longer average life (40-80 hours at 2650°K; AC or DC heating) and operational stability than standard or sharpened hairpin cathodes. This also reduces specimen damage by energetic ions commonly originating from impurities in normal tungsten sources. Similar pointed filaments of high purity tantalum, rhenium and niobium have specific properties particularly useful for low-temperature microscopy. Best results were consistently obtained with new types of etched molybdenum or stainless steel caps, the key element of which is a replaceable disc aperture of thin (10-30μ) molybdenum foil with a precisely centered small hole of 0.5mm (Fig. 1). The Mb foil is stable under electron bombardment which retards contamination and prolongs operational life of filament tips. Thin film configurations permit critical centering and height adjustment of filament tips determining adequate bias voltage and emission control. This practical cap design is applicable to both cathode and anode structures, combining optimum microgeometry and operational conditions for obtaining space charge free emission and significant field enhancement.

When used with compensated double condenser systems of high resolution instruments (Siemens Elmiskop I, Hitachi HU-11), these point sources provide improved microbeam illumination characterized mainly by: (a) <u>High specific brightness</u> of 5 - 25 x 10^5 A cm^{-2} sterad.$^{-1}$ measured reproducibly at final screen level. This gain in brightness is an order of magnitude larger than comparable values obtained with W hairpin filaments in standard gun (Fig. 2) at the same temperature (2680°K). Mb thin-film caps give highest values, surpassing the performance of a special steel cap (D) with 0.5mm hole which was developed in collaboration with Dr. K. Yada as described in another publication. This high brightness is partly ascribed to field enhancement by the Schottky effect. (b) High coherence, resulting partly from the smaller illumination angles made possible by increased source brightness. Transverse coherence lengths of 60 to 600 Å can be achieved by using condenser apertures of 100μ-10μ. Under favorable conditions, 50 to 60 Fresnel fringes were recorded (Fig. 3). This also gives enhanced contrast and improved image quality, especially when dealing with biological specimens (Fig. 4).

Based on our evaluation of average gun performance during the past decade, and in agreement with the results of Hibi and Yada (1,3), Maruse et al. (4), point cathodes have proved to be consistently superior to normal hairpin cathodes. Coherent microbeam illumination of high brightness already enables the operator to optimize instrument performance under direct observation at high electron optical magnifications. The reduced spread of emission energies at the low beam current (0.5-1.5μA) usually required to reach optimum operating conditions may also contribute to regular attainment of 2.8Å point resolution with axial illumination. Mb guns operating in ultrahigh vacuum are also being investigated as field and T-F emission sources suitable for microscopy by wavefront reconstruction.

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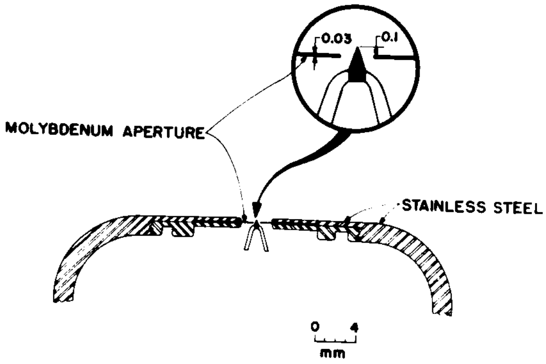

Fig.1: Sketch of improved cathode cap featuring disposable aperture of thin molybdenum foil with central small hole for filament tip adjustment.Basic cap body of Mb or steel serves as stable support for key Mb aperture which can be varied to give different modifications of standard cap design.

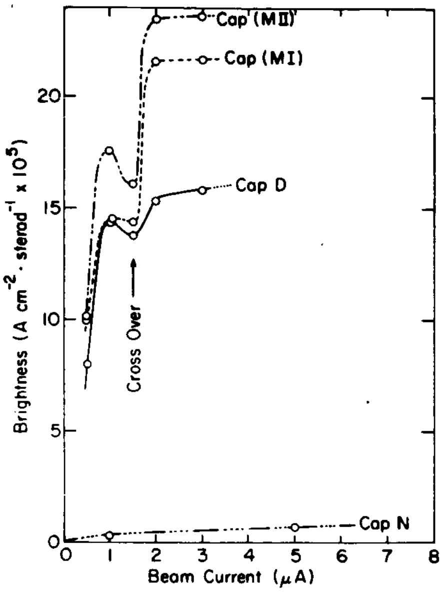

Fig. 2. High brightness at low beam current of tungsten point cathode in Mb-thin film caps (MI= stainless steel base; MII=Mb body), and in special small-hole cap(D), compared with much lower values of normal W hairpin filament(T=2680°K) in standard gun cap(N).Measured at screen level; 75 kV;$\beta=10^{-3}$ rad.

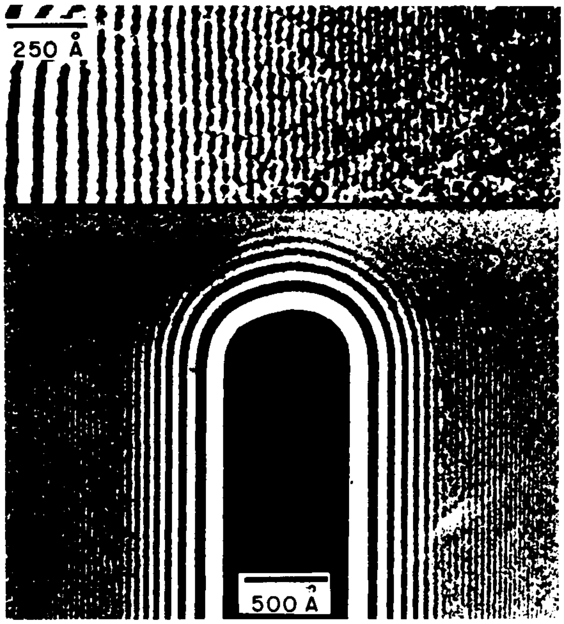

Fig.3. Electron micrographs of Fresnel fringes at edges of ZnO, MgO crystals recorded with tungsten pointed filament(T=2680°K)in improved cathode cap(0.5mmØ)at 75 kV,50μ condenser aperture;25,000 x electr. optical magnification.30 fringes in lower(ZnO) specimen;60 fringes in original upper(MgO)specimen insert.

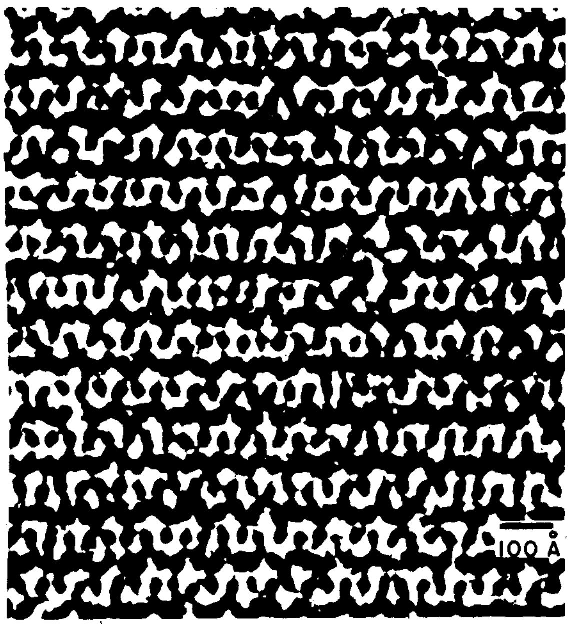

Fig. 4. High resolution electron micrograph of catalase crystal stained with uranyl formate.Recorded with tungsten point filament in Mb cap(MII);75 kV;50μ condenser aperture.Notice periodic crystal lattice with subunit structures of ca. 8 -20Å.