Electron holography using Schottky field emission source: influence of the gun optical conditions

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1. INTRODUCTION

Electron holography inside a Transmission Electron Microscope (TEM) can be used to retrieve the phase of the incident electron beam after crossing the sample. Using an electrostatic Möllenstedt biprism, the beam can be split in two parts which are superimposed in an optical plane below the biprism wire [1]. If the beam is sufficiently coherent, an interference phenomenon can occur between the two parts of the beam. The interference pattern obtained can be used to retrieve the phase difference between the two overlapping beams.

The characteristics of the interference pattern (contrast, phase sensitivity, ...) are strongly related to the properties of the incident electron beam (brightness, convergence angle, ...). Indeed, high brightness is required to obtain good holograms; hence the choice of the electron source is critical. Three main types of electron source exist: thermionic sources, Schottky Field Emission Gun (SFEG) and Cold Field Emission Gun (CFEG) [2]. Our experiments have been performed using a SFEG, which is a good compromise between brightness and emission stability. However SFEG has a complex optics [3], including the adjustment of extraction voltage and gun lens, permitting to operate it in two major modes called "crossover" and "telefocus". We have studied the influence of these SFEG parameters as well as the illumination optical configuration on the electron hologram quality.

2. RESULTS

3.1 SFEG optics

SFEG are composed of a [100] oriented tungsten (W) tip coated by zirconium oxide (ZrO), from where electrons are extracted by an anode (Fig. 1 (a)). This extraction is thermally assisted by a tip heating current, which induce a mean temperature of 1800 K. The tip is surrounded by a suppressing cap in order to remove the electrons coming from other parts of the ZrO/W tip. However some electrons extracted from the other facets of the tip can pass through the extracting anode, and the electron beam thus obtained is composed of a central (100) emission and side-emission lobes coming from other W facets (Fig. 2 (b)). The two operating SFEG modes, "crossover" and "telefocus", which are strongly dependent on the gun lens and extraction voltage (Fig. 1 (c)), refers either to the case of an optical configuration creating an image of the source between the gun lens and the first condenser lens, or without any cross-over before condenser 1.

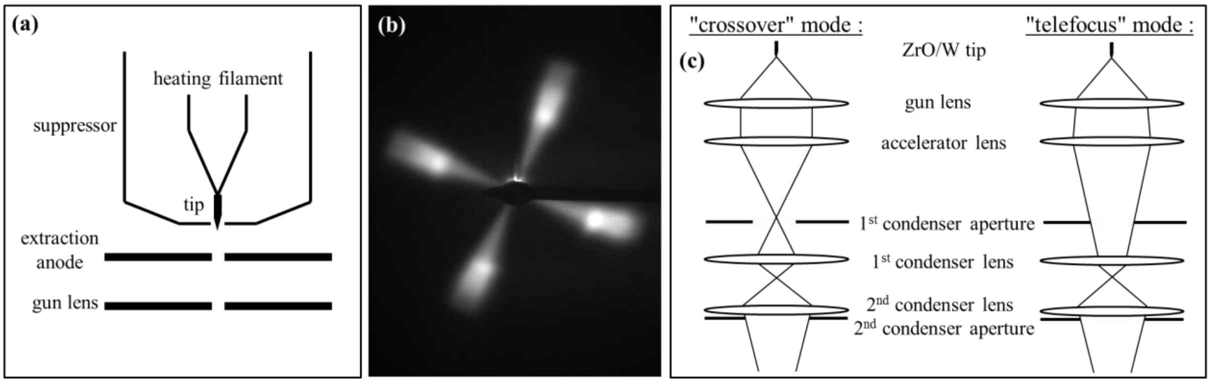

Figure 1. (a) Diagram of a SFEG, (b) image of an emission pattern of a ZrO/W tip showing side-emission lobes and a masked intense central emission from (100) facet and (c) optics diagrams of the condenser part for the two SFEG modes.

3.2 Experimental set-up and data treatment

Experiments have been carried out on two different TEMs. We use a Tecnai F20 equipped with a SFEG, a CEOS aberration corrector, an electrostatic biprism in the selected area plane and a GIF spectrometer; as well as a CM20 equipped with a SFEG. We have also used Gatan DigitalMicrograph software for data analysis and Geometric Phase Analysis (GPA) plugin for phase reconstruction of the acquired holograms.

3.3 Results

We present here the influence of condenser aperture used in both "crossover" and "telefocus" modes, and the difference of behavior related to these two configurations. We see (Fig. 2 (a)) that the hologram contrast is inversely proportional to the mean intensity in "crossover" mode. This phenomenon can be easily explained using the Van Cittert Zernike theorem. It predicts, for a sufficient source-image distance, that the spatial coherence degree of the source is equal to the Fourier transform of its normalized intensity. Hence we can gain in intensity, using bigger condenser apertures allowing bigger apparent source, only at a loss of spatial coherence, which induce a loss of contrast. We can confirm this behavior in "telefocus" mode (Fig. 2 (b)), either with the first aperture (C1) or the second aperture (C2). But this observation is not verified when switching the two aperture types. A gain in intensity using C1 (70 µm) instead of C2 (70 µm and 30 µm), can lead to a gain of contrast. It can be explained regarding the side-emission lobes contribution. Indeed, C1 permits to cut the side-emission lobes of the ZrO/W tip in "telefocus" mode. These lobes come from electrons with a low spatial coherence which considerably decrease the global hologram contrast.

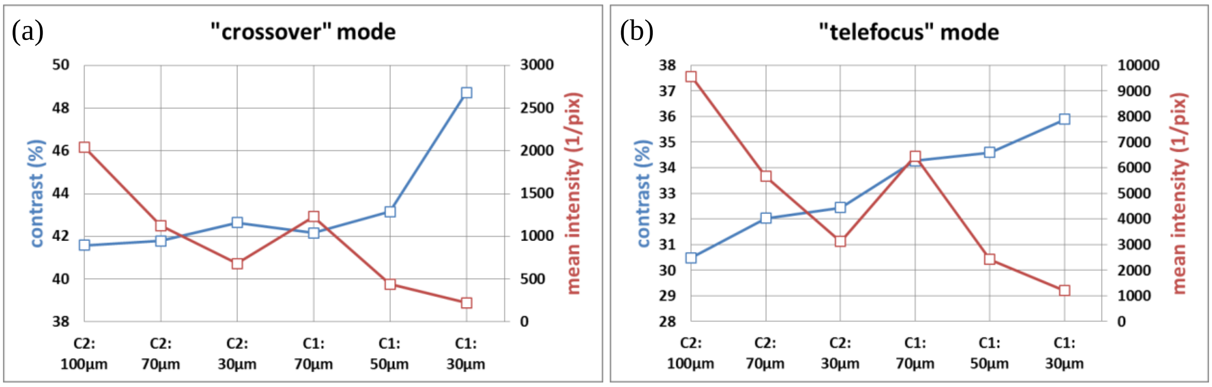

Figure 2. Hologram contrast and mean intensity in both (a) "crossover" and (b) "telefocus" modes, depending on condenser aperture conditions.

3. CONCLUSION

We have performed different experiments in order to better understand the influence of SFEG parameters, namely gun lens, extraction voltage, and condenser aperture settings on electron hologram quality, in both "crossover" and "telefocus" modes. We show a difference of behavior between these two modes and the influence of side-emission lobes. In order to better understand the physical origin of these lobes and their influence on the beam coherence, we have also performed Electron Energy Loss Spectroscopy (EELS) on the emission lobes and compare it with the (100) central emission.

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