AREA SELECTIVE DETECTOR OF LOW ENERGY ELECTRONS

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The aim of this work is to design a detector for the angle and energy-selective detection of signal electrons in very low energy scanning electron microscopy (VLESEM), based on the thinned back-side directly electron-bombarded CCD sensor (EBCCD). The principle of the VLESEM operation and electronics of the detector are described.

A schematic arrangement of the optics of the VLESEM for which the detector is considered was presented and described formerly [1,2]. The electron optics uses the Wien filter for the separation of the signal and the primary electrons beams and therefore makes possible to direct the main part of the signal electron beam to a suitable detector (Fig. 1). The principle of the operation is as follows:
The focused primary beam - probe - is scanned by the deflection system over the specimen in the scanning matrix of m-lines by n-columns. The signal beam is in every moment directed by the Wien filter and transport optics to the CCD sensor. The electrons of the beam cover o-lines by p-columns of the CCD sensor. The probe stays in every point of the scanning pattern "m by n" for the time needed for generation of an optimum amount of electrons in the potential wells of CCD. The image created in CCD corresponds to the angular distribution of the signal electrons of one point of the specimen. After reading this "o by p" image from CCD we process it in a suitable way to obtain one point of the "m by n" image on the display. This procedure is repeated for every point of the "m by n" pattern of the specimen. Let us consider the resolution for the specimen, i.e. (m x n) = (512 x 512) and the resolution for the CCD, i.e. (o x p) = (80 x 80) as fully sufficient. We would like to create the image of the specimen on the display in max. 10 min. According to this data, the maximum time for the accumulation of the charge in CCD plus for the processing of the data is $t = 600s/512 \cdot 512 = 2.3$ ms. This short time is the main reason why we cannot use any commercially available camera. Such cameras are usually optimized for very high integration and process time (slow-scan CCD cameras) and are equiped with high resolution sensor. The second reason is to have possibility to adapt the detector easily to the new experimental reqirements.

In VLESEM we decided to use the CCD sensor in the direct electron-bombarded mode. That is because we must accumulate the charge in a short time at low energies of the electron beam. From the point of speed the key parameter of the EBCCD is the electron bombarded semiconductor (EBS) gain G (a number of signal electrons in the potential well generated by one incident electron) which is related to the incident particle energy E. In the case of the real CCD sensor we must calculate the EBS gain G as $G = E \cdot \varepsilon(E) / (3.65\ eV)$ where $\varepsilon(E)$ is the detection efficiency of the CCD. In practice, the front-side illuminated CCD shows a reasonable efficiency ($\varepsilon > 0.1$) at an energy from 8 - 12 keV upwards, depending on type of the sensor. The available thinned back-side illuminated CCDs have an efficiency higher than 0.1 at energies below 5 keV. To meet our resolutin and timing requirements we chose the back illuminated high performance CCD sensor CCD39-02 (80 x 80 pixels) from Marconi. For simplicity, for well capacity 300 x 10^3 electrons and uniform distribution of the signal beam the total number of the signal electrons to be generated in all potential wells is $N_w = 300{\cdot}10^3 \cdot 80 \cdot 80 = 1.9{\cdot}10^9$ electrons. We assume signal beam current $I_b = 10^{-9}$ A. To generate such an amount of electrons we need the sensor with $G = N_w \cdot q/I_b \cdot t = 1.9{\cdot}10^9 \cdot 1.6{\cdot}10^{-19}/1{\cdot}10^{-9} \cdot 2{\cdot}10^{-3} = 152$. From equation above the needed $\varepsilon(5\ \text{keV}) = 152 \cdot 3.65/5{\cdot}10^3 = 0.11$. Consequently, the thinned back-side illuminated CCD could fulfil our requirements.

The electronics to control the CCD sensor and to process the signal data is based on the digital signal processor (DSP) from Analog Devices ADSP-2181 (Fig. 2). DSP generates clock signals to operate image-area, store-area and readout-register gates of the frame-transfer operation CCD image sensor and a synchronous clock signal for the 12-bit analog-to-digital converter. Clock pulses for CCD are buffered and level-shifted by the clock drivers and outputs to the image sensor. The analog output signal from CCD is synchronously converted by the 12-bit AD9220 A/D converter, buffered by the line driver to the processor data bus, read and processed.

The detector for the area selective detection of low energy signal electrons was developed and measurement under electron bombardement is carried out. The experimental configuration, the sensor output signal measured for energy up to 5 keV and radiation damage due to bombardment will be presented. The experiment is supported by the grant no. 102/00/P001 provided by the Grant Agency of the Czech Republic.

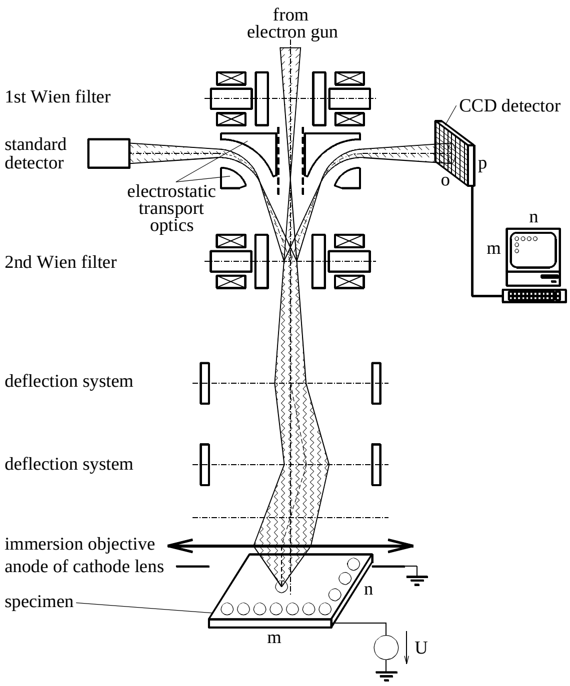

Figure 1: VLESEM operation.

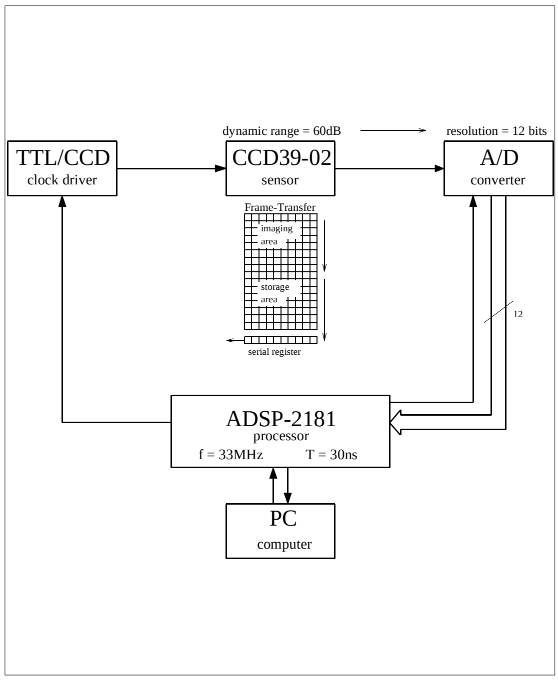

Figure 2: EBCCD electronics.

References
1. Horáček, M. (1998) Journal of Computer-Assisted Microscopy, Vol. 10, No. 1, 23.
2. Horáček, M. (2000) Proc. EUREM 12, Brno, Vol. III, I 477.

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