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A Low-Noise, Two-Channel STEM EBIC Metrology System

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EBIC imaging is the association of the electronic current an electron beam generates in a sample with the beam's position. EBIC has been in use since the 1960's [1]. Until recently, the term "EBIC" referred exclusively to contrast, most often measured in the SEM, from current generated by the separation of beam-induced electron hole pairs (EHPs) in local electric fields. Recently [2], a new mode of EBIC, secondary electron emission EBIC (SEEBIC), was demonstrated in STEM. When the electron beam is incident on a sample, secondary electrons (SEs) are emitted leaving behind holes; SEEBIC measures the current produced by these remaining holes. The SEEBIC is typically 1000× smaller (and thus harder to detect) than standard EBIC where a sample contains local electric fields, in part because many more EHPs are produced than SEs in a given beam interaction. Compared to standard EBIC, the smaller interaction volume of SEEBIC also allows for *much* higher spatial resolution, down to atomic length scales [3]. SEEBIC provides a quantitative measure of *all* SEs leaving a sample, and can also produce contrast based on local electrical conductivity [4,5] and temperature [6].

Most EBIC systems have been designed for measuring the large currents associated with standard EBIC. But SEEBIC, and especially SEEBIC-based metrology, requires a substantially higher fidelity current measurement scheme. We have developed a two-channel STEM EBIC solution capable of high-sensitivity, low noise measurements of both EBIC modes. As a simple demonstration of the system's sensitivity, we acquire EBIC from a single Pt electrode in Fig. 1A. In the absence of local electric fields, the signal is entirely SEEBIC, with edge and surface features consistent with secondary electron contrast. With an 80 pA probe current, the SEEBIC signal on the interior of the electrode is ~600 fA. Variations in the surface texture, modulating the signal by 10's of fA, are clearly resolved on both the electrode, to the right, and the SiN membrane, to the left. The EBIC image is raw, with no post-processing or filtering applied, and the FFT of the image is devoid of any peaks that would indicate periodic noise.

In this presentation we will outline the features of the STEM EBIC system and discuss the unique metrology opportunities its unprecedented EBIC image quality presents. As an example, Fig. 1B shows images acquired on a Pt electrode adjacent to a heater. With the heater off, STEM EBIC on the electrode is mostly uniform. Increasing heater power throughout the image produces an obvious increase in EBIC signal with temperature [6] in the raw, unprocessed EBIC image. This device exhibits a temperature gradient in both space (left to right) and time (top to bottom), all in the same imaging frame, with signal increasing as much as 25% across the image, corresponding to a temperature change of ~600 K [6]. We will also discuss the advantages of a two-channel EBIC system, such as the ability to separate contrast from standard EBIC and SEEBIC in images where both are present. We will demonstrate imaging of samples, produced via both lithographic patterning and FIB liftout, on EBIC-optimized, Si-based substrates [7].

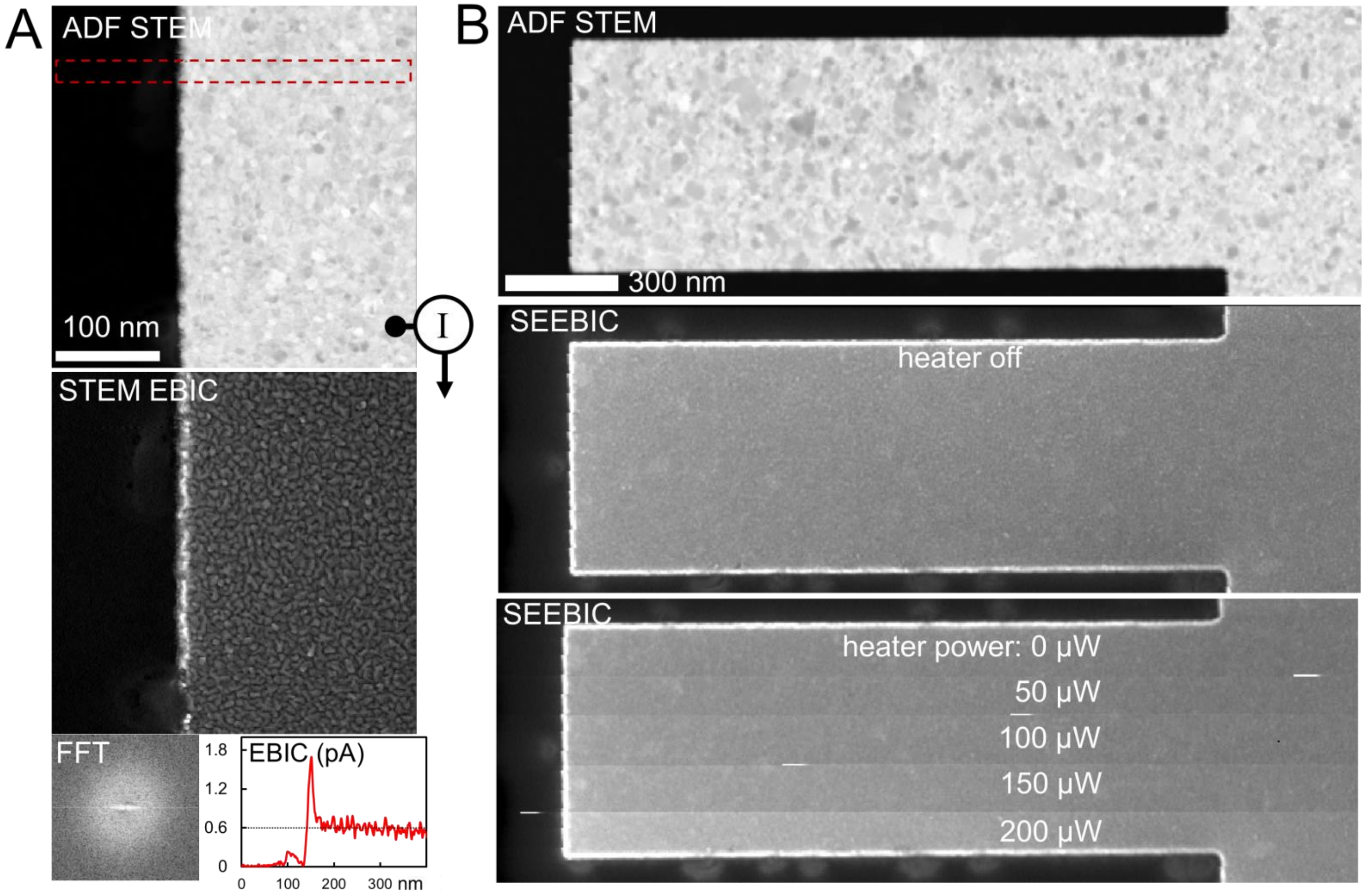

Figure 1. In both (A) and (B), ADF STEM and STEM EBIC images, showing a Pt electrode patterned on a SiN membrane, are acquired simultaneously, with EBIC measuring current generated on the electrode producing SEEBIC contrast. All images are raw – no post-processing or filtering has been applied. The plot in (A) shows a line profile of the EBIC signal acquired in the red region of the ADF STEM image in (A). SEEBIC on the electrode is 600 fA and was acquired with an 80 pA probe current. An FFT of the EBIC image is entirely devoid of any signatures of periodic noise. (B) A heater surrounds the electrode on three sides just outside the field of view to the left. The heater is off in the middle image and power is increased in steps, as indicated, over the course of the lower image, increasing the EBIC signal with each step. Probe current is 320 pA. Images in (A) are 256 pixel squares and in B are 512×180, and all images are acquired with a ~3 minute frame time.

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