Fabrication and characterization of a fine electron biprism on a Si-on-insulator MEMS chip

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Previous attempts to make ultra-narrow biprisms have included glass fibres coated with metal or patterned SiNx with focused ion beam. None of these attempts have provided a reproducible method of making ultra-narrow biprisms with perfect control over their dimensions. Here, we illustrate an approach that can be used to fabricate a biprism that has a rectangular cross-section and is located between two counter electrodes that are at the same height. We pattern the biprism in the top Si layer of a Si-on-insulator (SOI) wafer. The wafer consists of a micron-thick single-crystalline Si layer that is isolated electrically from its substrate and can be left free-standing using an etching process. When combined with microelectromechanical systems (MEMS) processes, structures can be patterned down to nm scale in three dimensions. In this way, the width of the biprism and the distance to the counter-electrodes can be chosen to have dimensions down to ~100 nm. A further advantage of using an SOI wafer to fabricate a biprism is the large Young's modulus of the single-crystalline Si biprism (170 GPa), when compared with that of a conventional biprism made from glass (~70 GPa). In addition, the two counter-electrodes can be biased independently. A custom-made aperture rod have been designed and fabricated to support and electrically contact the MEMS-based biprism. In order to test its performance, the biprism was mounted close to the SA plane in a Philips CM20 TEM. The electron deflection was measured by recording the shift of a diffraction spot as function of applied voltage. The measured deflections are compared with predicted deflections and with similar measurements made using a conventional biprism on an FEI Titan TEM. The deflection is a factor two greater for the new rectangular biprism for the same applied voltage. The measured interference fringe spacing, contrast and overlap width achieved using the new biprism are presented. Here, the maximum voltage that can be applied is limited by the distance between the biprism and the counter-electrodes, which can be increased in future designs. In order to demonstrate the imaging capabilities of the new biprism, an off-axis electron hologram of a MoS_2 flake was recorded in a Philips CM20 TEM. In the future, the biprism will be mounted in an image-aberration-corrected FEI Titan TEM, in which the electron optics offers greater flexibility in both normal and Lorentz imaging modes.

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