Applications of focused electron beam processing

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Focused electron beam induced processing is a high resolution nanostructuring technique for local deposition and etching of materials. In analogy to the well established focused ion beam methods, gas assisted etching (GAE) and ion beam induced deposition (IBID) a suitable precursor gas is dispensed through a nozzle in close vicinity to the incident beam. Depending on the precursor chemistry, a reaction is induced by the electrons, leading to either a deposition caused by fragmentation of precursor molecules or to a reaction between the adsorbed molecules and the substrate material, resulting in volatile products and thus etching of the substrate material. Since the reaction is confined to the area exposed by the electron beam, this technique allows high resolution nanostructuring with feature sizes well below 50 nm. Furthermore, since the process is solely chemically induced, unwanted side effects observed for ion beam based processing, such as ion implantation or sputtering are absent.

Although a large number of experimental data on electron beam induced deposition (EBID) and, to a lesser extend, on etching is reported in the literature, many aspects of the involved physical and chemical mechanisms are still poorly understood. This paper will give a brief overview of the current state of research and will illustrate the potential of the technique showing several examples of its applications. In particular, two recent applications in the area of semiconductor fabrication (mask repair and circuit editing) are presented.

With the ever shrinking feature sizes of photo masks, repair and repair validation of current technology type masks has become a substantial cost factor in overall mask production cost. In this context, the introduction of high-resolution electron-beam assisted deposition and etching has been an enabling technology to keep up with the increasing demands on current and next generation photomask repair. In this paper we will present an overview of key features of our e-beam based mask repair tool, discuss 45 nm and future node requirement and demonstrate current repair performance for standard binary (Chrome on Quartz) and phase shifting masks. In addition, feasibility studies for the repair of next generation technologies such as EUV mask, EUV blank and imprint template repair will be presented.

In the area of circuit editing focused ion beam tools have been widely used for debugging and rewiring of prototype integrated circuit during the design phase. Again, due to the shrinking dimensions of modern integrated circuits, FIB based processing is reaching its limits in terms of resolution and achievable aspect ratios. We have investigated the feasibility of e-beam based circuit editing and results including high aspect ratio via etching, copper line cutting and backfilling of vias with low resistivity conducting material will be presented.

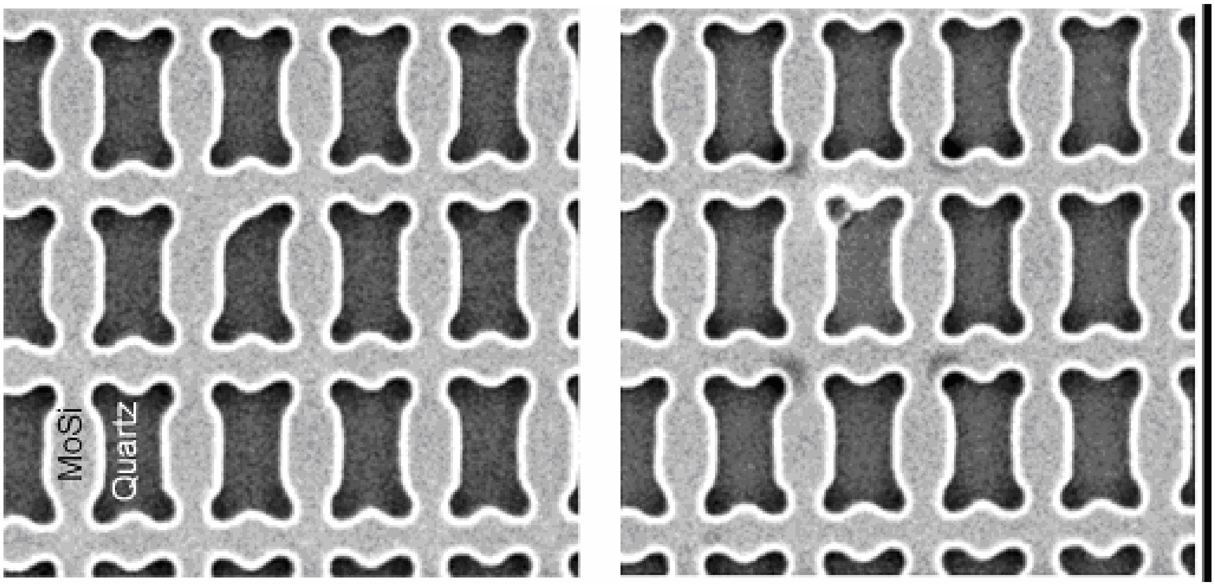

Fig 1: Pre-repair image of an ~50 nm sized extension defect on a contact hole area of an attenuated phase shift mask (left side). Same area after repair by electron beam induced etching of excessive Molybdenumsilicid adsorber material (right side).

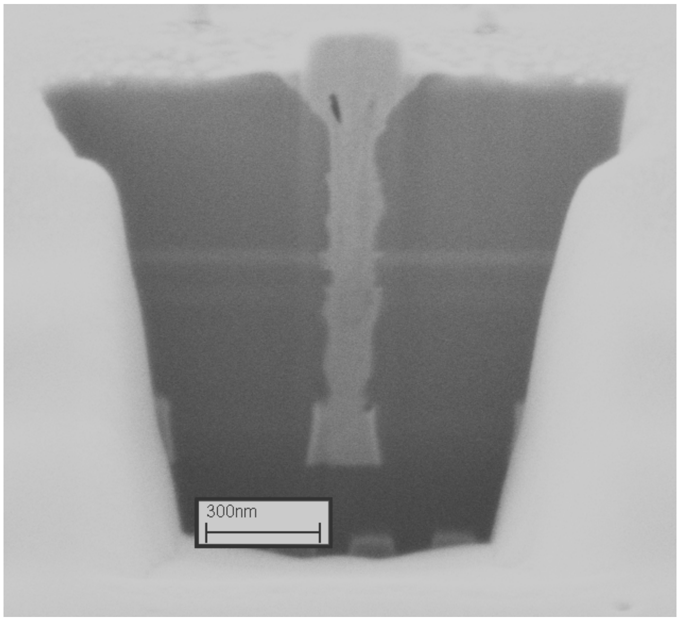

Fig. 2: Cross-section of a circuit editing type process step, including etching a via through inter-layer dielectric to the M1 interconnect layer by electron beam induced etching and backfilling the via with conducting material by electron beam induced deposition. Minimum via width is less than 100 nm, with an aspect ratio of 10:1.