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Automated Sample Preparation of Nanoscale Devices for FESEM

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Rapid, efficient and automated sample preparation of nanoscale devices has been demonstrated for field emission scanning electron microscopy (FESEM). [1-3] To prepare a cross section, a cleaved or cut surface is mechanically ground to a 1 μm or better finish. This surface is then treated by using a combination of automated processes including argon – oxygen plasma cleaning (PC), ion beam etching (IBE), reactive ion etching (RIE), and ion beam sputter coating (IBSC).

Application examples will be presented of microelectronic devices at the 45 nm node containing transistors based on Ti rather than Si - rich phases. Cross sections of these materials oxidize easily, forming an oxide layer following exposure to air containing molecular oxygen. [4] The advantage of not breaking vacuum during stepwise sample preparation will be demonstrated.

The preparation protocol is as follows. The first step is to clean the cross - section in an $Ar/25\%O_2$ plasma, followed by planarization at a low incident angle using Ar^+ directed by a hollow anode discharge (HAD) ion source. At this stage, the surface is free of hydrocarbon contaminants, deformation and oxidation (Fig. 1). With no residual carbon or oxygen present, selective etching by RIE can delineate the phases present. The sample is placed on the powered electrode of a parallel plate reactor, and CF_4/O_2 is emitted at a controlled flow rate and pressure. RF power is applied to the reactor, and a matching network ensures stable operation during a timed sequence.

Repetition using $10\%O_2$ rapidly establishes optimal selective etching of the Si – rich phases (Fig. 2). If $27\%O_2$ is used, the Ti – rich phases are selectively etched (Fig. 3). These results correlate with those obtained in a transmission electron microscope (TEM). [5] A thin (< 2 nm), featureless and electrically conductive metal layer is deposited to further optimize FESEM imaging. The target of Iridium (Ir) is positioned between the ion source and sample, and its ions are sputtered by Ar^+ onto the surface of the cross – section.

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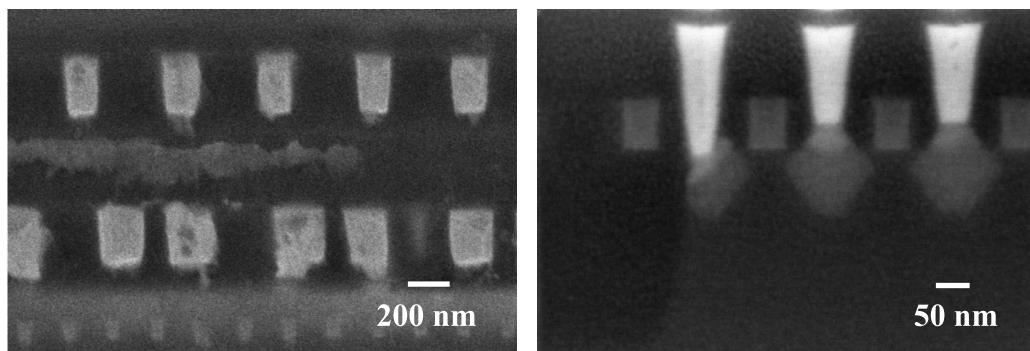

Fig. 1: FESEM (5 kV) images of 45 nm scale microelectronic device before (left) and after (right) PC + IBE. A 2 nm thick Ir coating was deposited prior to imaging.

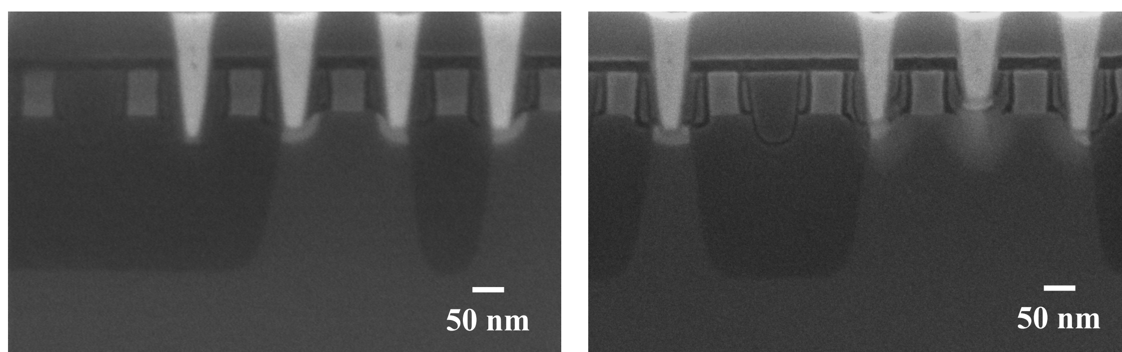

Fig. 2: FESEM (5 kV) images of planarized surfaces after a 1.5 min. (left) or 2.5 min. (right) $CF_4/10\%O_2$ RIE. The Si – rich phases are selectively etched. A 1 nm thick Ir coating was deposited prior to imaging.

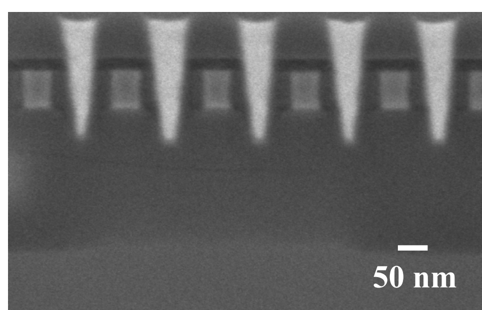

Fig. 3: FESEM (2 kV) image of a planarized surface after a 3.5 min. $CF_4/27\%O_2$ RIE and prior to Ir coating. The Ti – rich phases are selectively etched. This result correlates with that obtained by TEM in Ref. 5.

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