Selective SiO₂ etching in three dimensional structures using parylene-C as mask

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This abstract describes an application of an easy and straightforward method for selective SiO₂ etching in three dimensional structures, which is developed by our group. The application in this abstract is the protection of the buried-oxide (BOX) layer of a silicon-on-insulator (SOI) wafer against SiO₂ hard mask stripping in BHF after deep reactive ion etching (DRIE) in the device layer, where the BOX layer serves as etch stop. It enables further processing like refilling of trenches and other structures with preservation of the BOX layer, which can serve as sacrificial layer or electrical isolation. The BOX layer protection is done with parylene-C. This is a poly(monochloro-p-xylylene) polymer, which is traditionally used to coat implantable devices [1], used as protective packaging material in (chemical) sensors [2], or as actual shapeable material in devices [3]. The presented method adds mask material for selective SiO₂ etching to the list.

To demonstrate this method, a simulated BOX layer is used. First, a plane 100 mm <100> double side polished Si wafer was cleaned in HNO₃ and HF (step A in figure 1), after which a 1 μm SiO₂ layer was grown via wet thermal oxidation at 1150°C of the wafer (step B). This layer was patterned with a pattern of 3 μm wide trenches via conventional I-line photolithography and SiO₂ etching in an Adixen AMS100 reactive ion etching system (step C). The trenches were etched 57 μm deep with a Bosch process using an SPTS DRIE system (step D). After stripping of the photoresist and fluorocarbons in a TePla GIGAbatch 360M barrel etcher using an oxygen plasma and cleaning in HNO₃, a layer of 400 nm SiO₂ was grown via dry thermal oxidation at 100°C (step E). This configuration mimics a SOI wafer with a device layer of 50 μm and a BOX layer of 400 nm. Then, a 2 μm thick conformal layer of parylene-C was deposited via CVD in an SCS PDS2010 system (step F). The dimer precursors were first vaporized at 200°C and subsequently pyrolized at 690°C to create monomers. These monomers were deposited and subsequently polymerized on the surface in a vacuum chamber at 25°C. The chosen thickness is more than half the trench width, ensuring full filling of the trenches. The substrate was put horizontally into the same NanoLab system and a FEI Sirion HR-SEM.

Results are summarized in figures 2 to 5. All shown cross-sections were made by breaking, except the parylene-C filled trench. This one was made via dicing. The initial SiO₂ hard mask and the simulated BOX layer are visible on the SEM image shown in figure 2. The parylene-C filled trench is shown in figure 3. The dicing deformed the elastic parylene-C and disrupted the interfaces with the Si. figure 4 shows the bottom of the trench after BHF etching of hard mask. It is visible here that the parylene-C bulk is etched almost completely to the bottom and that a thin film remains at the bottom and on the sidewalls, protecting the simulated BOX layer against BHF. After parylene-C stripping in piranha, it is clearly visible that the SiO₂ remained intact at the bottom of the trench (figure 5), but is removed from the top (figure 6).

It can be concluded that the proposed method is indeed a suitable method for the protection of the BOX layer when a SiO₂ hard mask needs to be removed after trench etching and that it can be translated to mask material for selective SiO₂ etching in three dimensions, which is future research.