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Accurate parameter extraction for the simulation of direct structuring by ion beams

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Motivation

"Precise 2D/3D Simulation of ion beam structuring"

Most important occuring effects:

Dependence of the sputter yield on the angle of incidence

Effects due to scattered ions

Redeposition of sputtered atoms

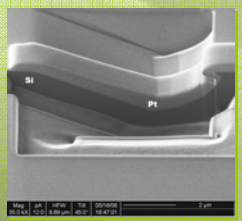
2D trench structure

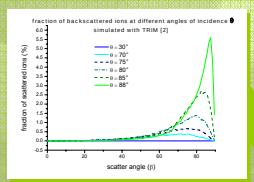
Determination of material specific parameters

Dedicated experiments

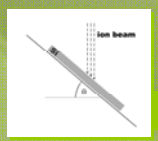
and

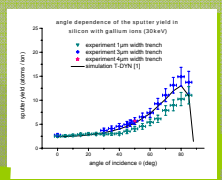
Monte Carlo simulations





Trenches with different widths were sputtered into silicon substrates tilted under an angle of θ (Ga ions, 30keV). Subsequent covering of the retilted trench via platinum deposition before cross sectioning allows the exact determination of the sputtered volume from the SEM image.



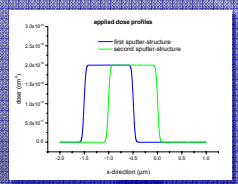


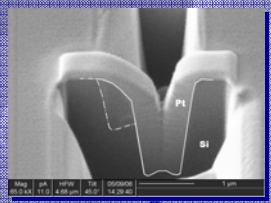
For small trench widths the redeposition of sputtered material can not be neglected and leads to decreased effective sputter yields. A trench width of about 3µm is sufficient. For comparison, simulation results obtained by the Monte Carlo program T-DYN [1] are included.

The knowledge of the fraction of scattered ions is necessary to incorporate the redeposition of sputtered material and secondary sputtering. However, the experimental determination of the angle dispersion of scattered ions at a predetermined angle of incidence is extremely elaborate. Thus, Monte Carlo simulations were used.

Simulation tool Ionshaper™

Comparison of experiment and simulation



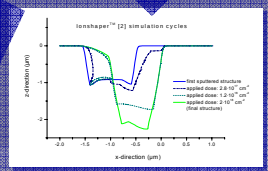


Comparison between the experimental (see above) and the simulated structure (see below) gives a good agreement. Especially, the redeposition, which virtually completely fills up the left half of the before sputtered trench, can be anticipated very well. In the SEM picture above, the dotted white line marks the first sputtered trench shape refilled by redeposition, the solid white line marks the final shape.

In this work, the simulation program Ionshaper™ [3][4] was used, which is developed in the framework of the FP6 Integrated Project CHARPAN.
It allows a 2D simulation of ion beam structuring by taking into account all aforementioned effects.

Simulation

To proof the validity and accuracy of the determined parameters and the program, a relatively complex structure was manufactured: first a 1µm wide trench was sputtered into silicon, which was subsequently overlapped by an identical second trench with an overlap of 0.5µm.



Conclusion

- **Identification of the most important material specific parameters to be determined for sputtering simulation:**
  angle dependent sputter yield + fraction of scattered ions
- **Procedures to determine sputter yield and fraction of scattered ions:**
  carefully designed experiments or Monte Carlo simulations
- **Results of this work:**
  angle dependent sputter yield
  → very good agreement between experimental and simulated data
  → test sputter structures and ion dose have to be adapted properly
  angle dependent fraction of scattered ions
  → Monte Carlo simulations (TRIM [2]) to avoid complex, time-consuming, and costly experiments
- **Use of our data within Ionshaper™ allows for a correct simulation of fabricated complex structures**

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