2D IMPURITY PROFILING WITH EMISSION-COMPUTED TOMOGRAPHY TECHNIQUES

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A new technique has been developed to extract two-dimensional impurity distributions from several one-dimensional doping profiles measured at different angles, using emission-computed tomography algorithms. A discussion of the effect of the number of angles, number of iterations, measurement noise, choice of the initial guess, and the size of the reconstructed array, will be presented.

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Two-dimensional measurements of impurity profiles in silicon have become an important issue in VLSI device design and process simulation. A new technique has been developed to extract two-dimensional impurity distributions using emission-computed tomography algorithms. Two-dimensional effects, such as the asymmetry due to shadowing of implants in lightly doped drain transistors, are device and process issues where knowledge of the doping profile is essential. The recent development of two-dimensional process simulators to investigate such effects requires measured impurity profiles to check the validity and accuracy of their simulations.

Traditional impurity profile measurement techniques, such as spreading resistance, SIMS, RBS, and capacitive measurements, are one-dimensional. Some efforts have been made to measure two-dimensional impurity profiles by selective etching of structures [1,2]. The present technique reconstructs the two-dimensional dopant distribution from several one-dimensional profiles acquired at different angles using algorithms originally developed for emission-computed tomography. A one-dimensional SIMS measurement at an angle θ to the surface normal of the structure effectively counts the number of impurities in each slice of the structure (Fig. 1). The counting of impurities in a thin layer by SIMS is directly analogous to the acquisition of emitted radiation from a human body in a medical tomographic study. A linear combination of the voxels in the silicon structure can be derived for each SIMS data point. Thus several SIMS profiles produce a system of equations that can be solved for the concentration of impurities in each voxel. The maximum likelihood estimator algorithm [3,4] was chosen to minimize the number of angles required and hence the number of necessary measurements, and because of its robustness with respect to measurement noise.

As part of extensive computer simulations done to explore the potential and limitations of this technique, a simulated two-dimensional impurity profile was generated for boron implanted at 800 KeV with a dose of $1 \times 10^{15}\mathrm{cm}^2$ through an oxide mask with an opening of 1μm and 45° side walls (Fig. 2 and 3a). Seven one-dimensional SIMS measurements were then simulated for this implantation. From the symmetry of the structure, six of these measurements also represented the data for negative θs. The thirteen one-dimensional profiles were then used to reconstruct the two-dimensional profile in 100 iterations (Fig. 3b). Additional simulations will be presented to show the dependence of the reconstruction algorithm on different parameters, such as the number of angles, the number of iterations, the acceleration factor, the size of the reconstructed array, measurement noise, and the choice of the initial guess.

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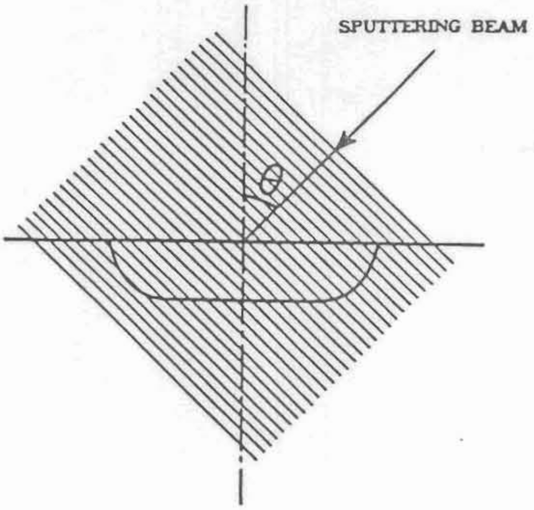


Figure 1. A SIMS measurement done at an angle θ to the surface normal of a structure counts the impurities found between adjacent diagonal lines.

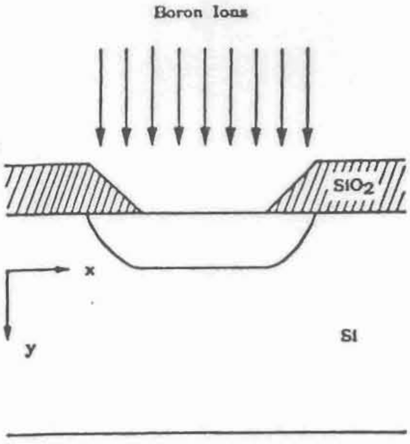
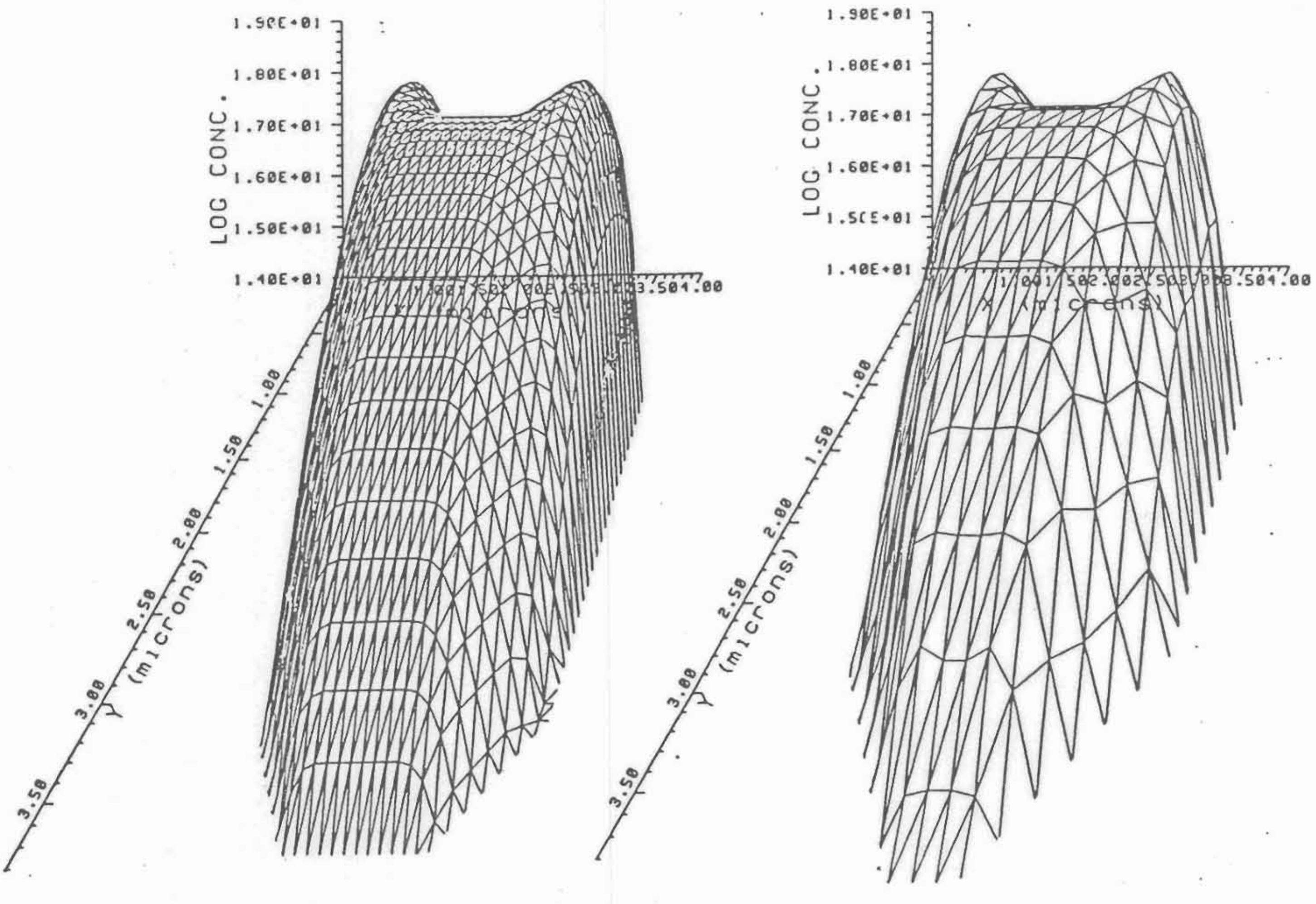


Figure 2. The physical structure used to create the simulated doping profile shown in Figure 3a.



a) b)

Figure 3. a) A perspective plot of a simulated two-dimensional impurity profile of 800 KeV boron implanted with a dose of 1×10^{15}cm^2 through an oxide mask with an opening of 1μm and 45° side walls. X is the lateral position and Y is the depth. Simulated SIMS measurements were made of this structure. b) The reconstructed two-dimensional doping profile using 13 angles and 100 iterations.