Dummy Feature Placement for Oxide Chemical-Mechanical Polishing Manufacturability

Ruiqi Tian*†, D. F. Wong*, Robert Boone†, Alfred Reich†

*Department of Computer Sciences, University of Texas at Austin, Austin, TX 78712
†Motorola Computational Technologies Lab, 3501 Ed Bluestein Blvd., Austin, TX, 78731
{ruiqi, wong}@cs.utexas.edu, {Robert_Boone, Alfred_Reich}@email.sps.mot.com

Abstract

Chemical-mechanical polishing (CMP) is a technique used in very deep-submicron VLSI manufacturing to achieve uniformity in long range oxide planarization [1]. Post-CMP topography is highly related to local spatial pattern density in layout. To change local pattern density, and thus ensure post-CMP planarization, dummy features are placed in layout. The only known previously published algorthm [3] for dummy feature placement is based on a very simple and inadequate model. This paper is based on a closed-form analytical model for inter-level dielectric thickness in CMP process by B. Stine *et al.* [7] and a model for effective local layout pattern density by D. Ouma *et al.* [5]. Those two models accurately describe the relation between local pattern density and post-CMP planarization [8]. This paper uses those two models to solve the dummy feature placement problem of a single layer in the fixed-dissection regime. An experiment, conducted with real industry design data, gives excellent results by reducing post-CMP topography variation from 753Å to 169Å, and compares favorably to the algorithm in [3], which only reduced the topography variation to 358Å.

1 Introduction

VLSI manufacturing uses chemical-mechanical polishing (CMP) to remove excess oxide deliberately deposited on surface of the wafer in order to achieve relative uniformity of inter-level dielectric (ILD) thickness. Uniformity of intra-die ILD thickness reduces process variation and thus improves predictability and manufacturability [1]. Post-CMP ILD thickness is highly correlated to pattern density distribution of existing features. Hence, one consideration to ensure CMP manufacturability arises from the fact that to achieve post-CMP planarization of ILD, pattern density distribution has to satisfy certain relations *prior* to the CMP process.

Dummy features are inserted into layout to change pattern density distribution. Dummy features are electrically inactive features that are not for the purpose of optical assistance. Therefore, given a model of the relationship between pattern density distribution and final topography for a CMP process, the dummy feature placement problem is to determine the amount and location of dummy features to place into the layout, such that certain constraints, such as electrical and physical design rules, are observed, and certain objectives, such as minimum or ranged variation, are satisfied by post-CMP topography.

Recent models of CMP by B. Stine *et al.* [7] and D. Ouma *et al.* [5] have enabled faster and more accurate prediction of ILD thickness from computing an effective initial local feature density. Base on those models, this paper proposes a two-step solution to the dummy feature placement problem for a single layer in the fixed-dissection regime, in which the layout is divided into a grid of small rectangles of equal sizes. The first step uses linear programming to compute the amount of dummy feature needed in each small rectangle. The second step then places the prescribed amount into each rectangle while optionally optimize certain local properties.

In the sections that follow, the models used by this paper and the only previous work known to the authors are reviewed in section 2 for completeness; section 3 describes notation and the two-step approach;

experimental results and comparison to the only previous work is in section 4; and finally conclusion is presented in section 5 along with some discussion.

2 Models for the CMP process

Several models were proposed for oxide planarization via CMP [4]. In contrast, the model by B. Stine *et al.* is not computationally expensive nor difficult to calibrate [7]. In that model, ILD thickness z at location (x, y) is solved to be

$$z = \begin{cases} z_0 - [K_i t / \rho_0(x,y)] & t < (\rho_0 z_1 / K_i) \\ z_0 - z_1 - K_i t + \rho_0(x,y) z_1 & t > (\rho_0 z_1 / K_i) \end{cases}, \quad (1)$$

where K_i is the blanket polishing rate, z_0 the height of oxide deposition, z_1 the height of existing feature, t the polish time, and $\rho_0(x, y)$ the initial pattern density. Figure 1 shows a schematic for some of the variables. Normally t is larger than $(\rho_0 z_1 / K_i)$ so final oxide thickness, by the second case of Eq. (1), is between 0 and

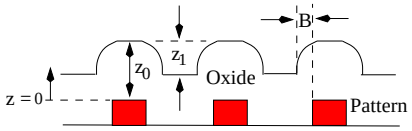

Figure 1: Some variables in CMP

$(z_0 - z_1)$. In addition, for a specific CMP process, all K_i, z_0, z_1, and t are constants. As a result, the final topography is determined by the initial pattern density $\rho_0(x, y)$.

In the simplest model for $\rho_0(x, y)$, the local spatial pattern density in a layout is used. An algorithm by Kahng *et al.* solves the dummy feature placement problem based on this model [3]. In their algorithm, the objective of minimizing final ILD thickness variation is translated to minimizing spatial density variation within all possible floating rectangular regions of given size (called *windows*). Obviously this Min-Variation formulation is correct for the simple model, and is very useful in the design phase to guarantee certain density range in layout.

However, more accurate modeling by D. Ouma *et al.* considers the deformation of polishing pad during polish [5]. The effective local density $\rho_0(x, y)$ is no longer directly proportional to local spatial pattern density, but calculated as the summation of weighted spatial pattern density within a weighing region. The weighing function $f(x, y)$ is an elliptical function. Size of the weighing region depends on the interaction distance, which is the length at which the relative weight in $f(x, y)$ drops to $1/e$. The interaction distance, whose value is typically several millimeters, depends on the specific condition of a CMP process, so calibration with direct measurements from test patterns is needed. To calibrate f, an elliptical f is assumed to be

$$f(x, y) = c_0 \exp[c_1 (x^2 + y^2)^{c_2}],$$

and then constants c_0, c_1, and c_2 are experimentally determined [8]. Figure 2 shows an example of f.

In the fixed-dissection regime, where the layout area is divided into a grid of small rectangles, spatial pattern density for oxide $d(i, j)$ is determined for each rectangle. f is discretized accordingly with respect to the grid. The discretized effective local pattern density $\rho_0(i, j)$ is then

$$\rho_0(i, j) = \mathrm{IFFT}[\mathrm{FFT}[d(i, j)] \cdot \mathrm{FFT}[f(i, j)]]. \quad (2)$$

Therefore, in effect, the CMP process is modeled by Eq. (2) as a low-pass filter through which the local pattern density d not only contributes to immediate but also short range ILD thickness within the weighing region defined by the interaction distance of f.