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A Feature-Scale Greenwood–Williamson Model for Metal Chemical Mechanical Planarization

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In this work, a new feature-scale model is proposed for investigating the interaction between the wafer pattern and individual pad asperities in the process of chemical mechanical planarization (CMP). Based on the contact mechanics equation and the modified Greenwood–Williamson (GW) model which captures the evolution of feature curvature and the modification of the pad asperity height distribution, the discrete convolution and fast Fourier transform (DC-FFT) technique is adopted and combined with the Picard iteration method to calculate the direct contact pressure distribution between the wafer surface and the polishing pad. The computed pressure is then used to determine the local removal rate of the underlying patterns and predict the evolution of the wafer surface profile. Furthermore, the method is extended to capture the metal dishing as the feature size changes. It is shown that the present model can avoid the false simulated results produced by directly applying the original GW model for CMP when the feature size approaches zero. Otherwise, the calculated surface profile and dishing values of pattern geometries are in good agreement with the experimental data. Therefore, this model can not only be used to simulate the evolution of the wafer surface for global planarization at lower technology nodes, but can also be applied to provide some basic design rules for improving the process parameters and reducing the time and cost for developing new architectures.

Key words: Feature-scale model, chemical mechanical planarization, fast Fourier transform, surface profile, dishing

INTRODUCTION

With the steady shrinkage of feature sizes and device geometry of modern integrated circuits (ICs), chemical mechanical planarization (CMP) has emerged as one of the most important solutions for surface global planarization. It has been widely used in manufacturing of interlevel dielectrics (ILDs), shallow trench isolation (STI), damascene metallization, and other novel process techniques.[1]

In the process of CMP, a wafer attached to a spinning carrier is pressed against a polymeric rotating pad. A slurry composed of chemical compounds and abrasive particles is deposited on the pad during polishing, and is transported to the wafer–pad interface by the pad. The wafer surface is polished by the cooperative interaction of chemical corrosion and mechanical abrasion. In spite of its apparent simplicity, the material removal mechanism of CMP is very complicated, and many aspects of CMP are not well understood. It is generally recognized that the wafer film surface is weakened by the chemicals in the slurry and then removed by the mechanical action among the wafer, the polishing pad, and the abrasive particles. Repetitive cycles of surface film formation, film removal, and metal dissolution result in eventual planarization of the structure.[2]

The removal rate, which is the most important topic of modeling of the CMP process, depends sensitively on the pattern geometry and density, and CMP may result in excessive erosion of the

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