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Stochastic simulation studies of molecular resists for the 32 nm technology node

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Abstract

Experiments and simulations suggest that low-molecular-weight resist materials could result in low line-edge roughness (LER) which is a critical parameter for the forthcoming technology nodes. Two positive molecular resist architectures are modeled with a stochastic lithography simulator and their LER behavior is quantified. The corresponding LER values obtained are less than 1nm, suggesting that such materials are promising for the fabrication of devices even down to the 32 nm node. Two-dimensional lattices with the molecular resist architectures are created and combined with the stochastic lithography simulator and a simple etching modeling algorithm, in order to test the transferred line-width roughness (LWR) on the gate region of the pMOS and nMOS transistors of an inverter cell designed with 40 nm nominal gate length. The role of the molecular resist architecture on the final LWR of transistor gate is discussed.

Keywords: Molecular resists; High resolution lithography; LER; LWR; Etching; Process simulation

1. Introduction

The influence of resist material and its architecture becomes important in the sub 45 nm patterning scale. Experiments and simulations [1–5], have shown that low-molecular-weight resist materials could result in low line-edge roughness (LER) which is a critical parameter for the forthcoming technology nodes.

In this work a stochastic lithography simulation [3–5] is combined with an electron-beam lithography module [6,7], and both are applied for simulating a CMOS inverter gate layout, design with 32 nm design rules. The drawn gate length under the pMOS and nMOS transistor regions is 40 nm. The objective is to model molecular resist architectures throughout lithography and etching taking into account fine details such as critical dimension (CD) and line-width roughness (LWR). Particular consideration is given on the effects of material molecular type, and acid diffusion conditions. Fig. 1 shows a qualitative representation of the modelling/simulation flow.

Section 2 discusses the modelling methodology, while on Section 3 the simulation results are presented and discussed.

2. Model description

In a previous work [6] it has been shown that molecular resist exhibited very low LER compared with polymer chains of the same overall radius of gyration, although the free volume of the molecular resist lattice was much higher than the corresponding polymer chain lattice (30% vs. 10%, respectively), due to the limited number of conformations of the molecular resist architecture that the algorithm was able to handle at that stage of its development.

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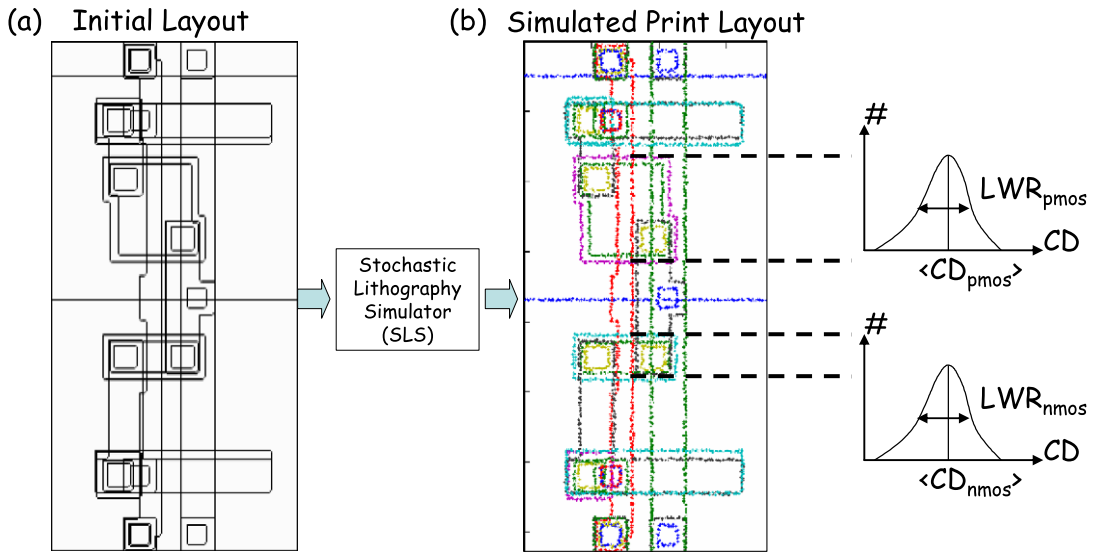

Fig. 1. Qualitative representation of the modeling process followed in this work.

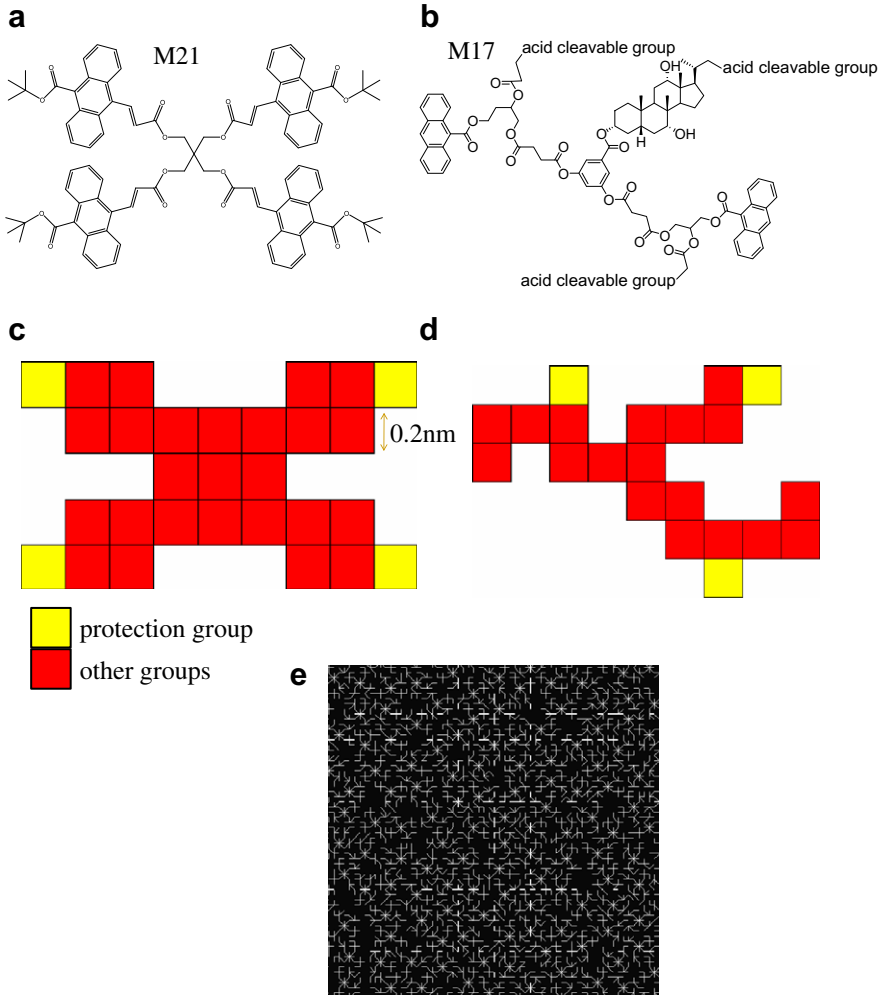

Fig. 2. Molecular resists (a) M21, (b) M17. Their digital representations are shown in (c) and (d), respectively. The radius of gyration is 1.6 nm for M21 and 1.3 nm for M17. (e) Magnified lattice of M21. Free volume is 5%. The value of 0.2 nm per site is chosen based on the minimum molecular group dimension in the molecules, and all chemical group sizes were expressed in terms of this.