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Published in:
Book of Abstracts. DTU's Sustain Conference 2015

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Proximity Effects in a Chemically Amplified Electron Beam Resist Patterned at 100 keV

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Electron beam lithography (EBL) is a patterning technique providing nanometric resolution. It is widely used in research, optical and nanoimprint lithography mask production, and parallel EBL is intended to be adopted in future next generation high through-put semiconductor device production [1]. Sub-20 nm patterning has been demonstrated on negative tone, epoxy-based chemically amplified EBL resists such as mr-EBL 6000 [2]. This material is characterized by significantly reduced dose sensitivity, which would provide faster, more cost-effective production.

When distances between structures are comparable to the intended critical (smallest) feature dimension, proximity effects (PE) caused by forward and back scattered electrons deteriorate the quality of the resulting pattern. PE on mr-EBL 6000 were observed when patterning with 10 and 20 keV electron beams, and compensated through dose modulation algorithms [3]. The present investigation focused instead on PE in mr-EBL at substantially higher electron energy and is to our knowledge new. To understand these conditions and their expected profound influence on PE, we patterned carefully arranged structures at 100 keV, and transferred them into a silicon substrate by reactive ion etching (RIE). We successfully patterned 50 to 500 nm wide lines, and we observed pattern deterioration when feature separation approached 5 times the line width (Fig. 1). We attribute this to PE. As a simple optimization, we showed how under-dosed patterns offer appreciable improvements in minimum obtainable pitch, and obtained analogous results in films thinner than 40 nm, an expected mandatory requirement to push manufacturing towards sub-10 nm half-pitch resolution [4].

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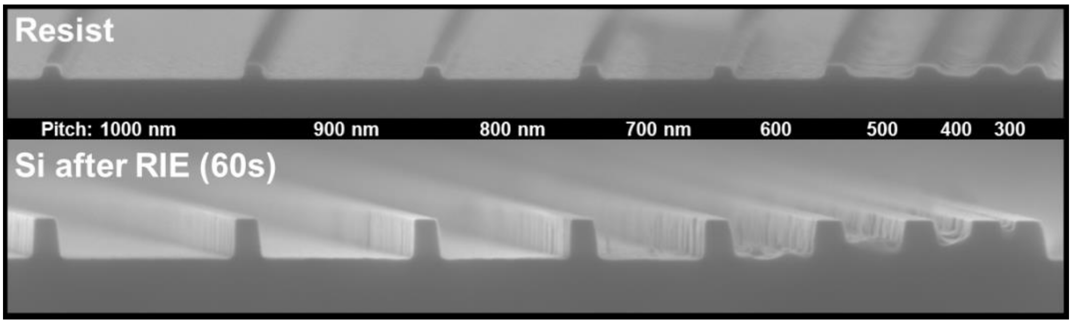

Figure 1 – Cross sectional SEM image of progressively closer spaced lines patterned in resist (a) and transferred into silicon through RIE (b). We observe overexposure in denser patterns because of PE; the resulting distorted pattern is this way reproduced into the underlying substrate.