Improving The Resolution Limit Of Electron Beam Lithography

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Fabrication of electronic and photonic devices with critical dimensions in the nanometre regime requires lithographic processes capable to provide highest resolution and excellent process control at reasonable costs. Future lithographic techniques that meet these demands rely on electron beam lithography (EBL) as part of the process flow. Masks for EUV lithography processes for example are primarily fabricated using EBL. Furthermore, Nanoimprint lithography (NIL) resorts to EBL for the fabrication of templates. In research, direct write EBL offers the high flexibility needed for prototyping future nano devices. Independent of the choice of the lithographic process, EBL must therefore be considered a key technology for research, development and production in nanoelectronics and nanophotonics.

The Advanced Microelectronic Center Aachen (AMICA) is applying EBL to the fabrication of templates for its in-house nanoimprint research activities as well as direct write processes for nanowire transistors, sensors and nanophotonic devices with critical dimensions well below 20 nn. To meet the challenging demands, a fine-tuned Leica EBPG-5000 TFE system is used, allowing fabrication of structures with feature sizes of 10nm and below [1].

Specific resist materials — primarily hydrogen silsesquioxane (HSQ), Shipley UVN30® and poly(methylmethacrylate) (PMMA) — are investigated concerning their suitability for the fabrication of nano devices and especially process modifications to enhance resolution and aspect ratio. In detail, megasonic-assisted development (MAD) [2,3] and supercritical resist drying (SRD) [4,5] are used to enhance their lithographic performance.

Fig. 1 and Fig. 2 demonstrate the improvement in development homogeneity using MAD. Development homogeneity and development depth are greatly increased. Futhermore, PMMA feature sizes significantly below 10nm can be achieved with MAD, representing near-ultimate resolution (Fig. 3).

Fig. 4 and Fig. 5 show decisive improvements in the maximum achievable aspect ratio and resolution using a SRD process instead of a conventional nitrogen blow process for resist drying. Resist features with high aspect ratios which collapse during conventional resist drying processes can be fabricated reproducibly with SRD. Aspect ratios above 40 can be realized using HSQ as resist material and SRD (Fig. 6). In addition, SRD techniques significantly reduce line edge and surface roughness of resist structures up to 20% [6].

Further process details and applications for MAD and SCR will be given in the talk.

References:

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[3] D. Küpper et al, J. Vac. Sci. Technol. B, to be published 2006
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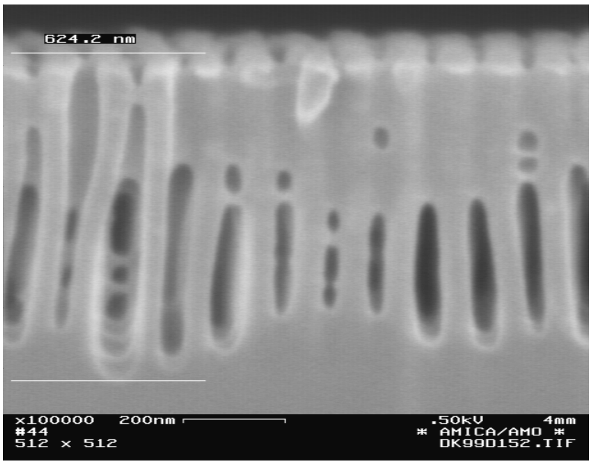

Figure 1: Dense holes in PMMA processed without MAD: inhomogeneous development

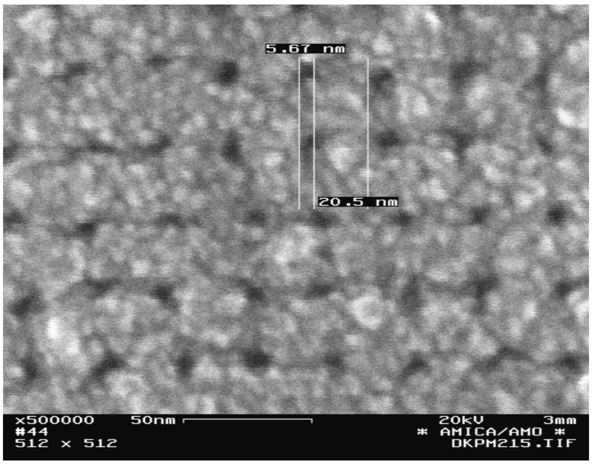

Figure 2: Dense holes in PMMA processed with MAD: ultimate resolution in the sub-10-nm regime. The sample was coated with a thin Cr layer prior to SEM inspection to avoid static

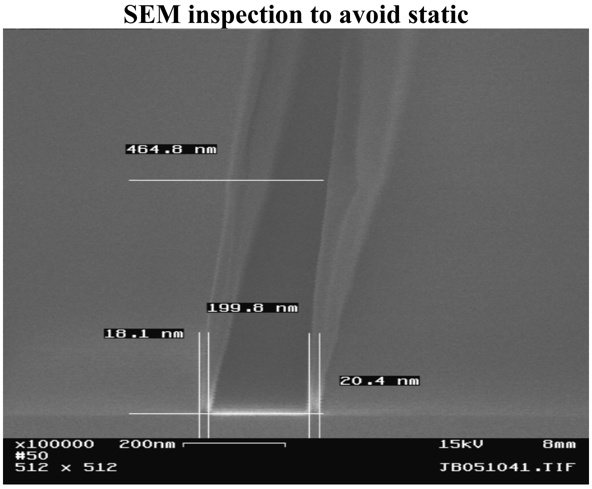

Figure 3: Dense HSQ lines processed with SRD: aspect ratio ~23

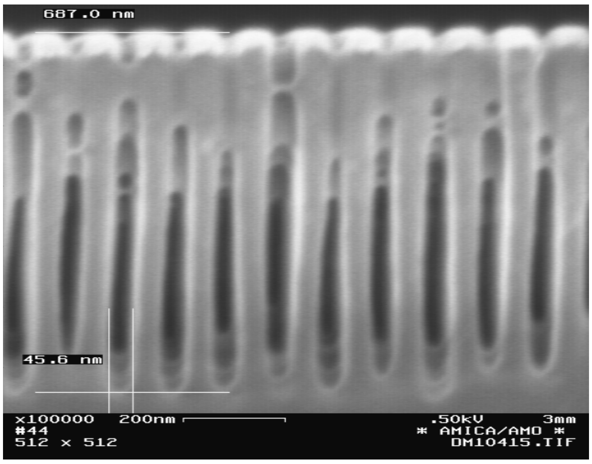

Figure 4: Dense holes in PMMA processed with MAD: homogeneity of development significantly improved

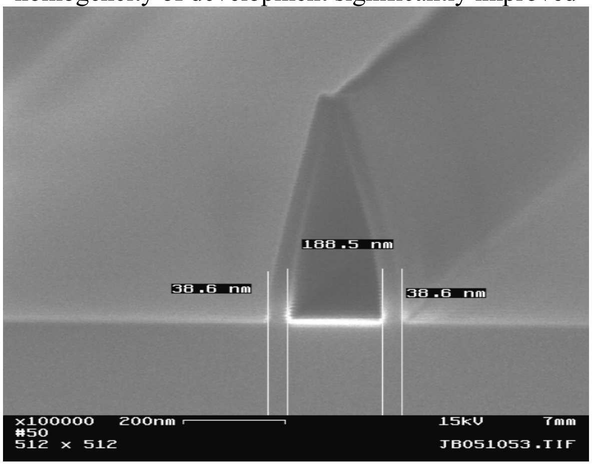

Figure 5: Dense HSQ lines processed without SRD: collapsed

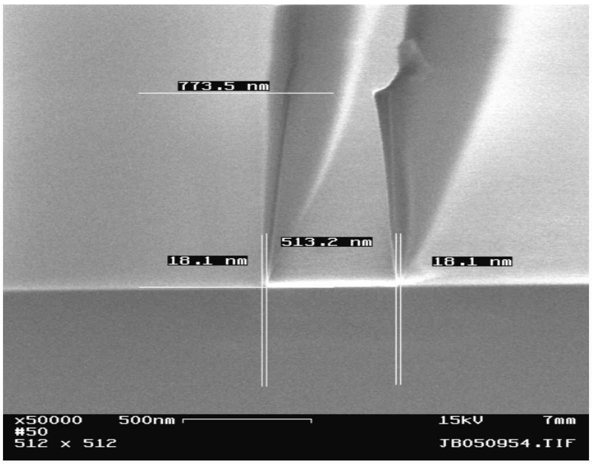

Figure 6: Semi-dense HSQ lines processed with SRD: aspect ratio ~40