Insoluble residual in ZEP520 electron-beam resist development

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ZEP520 (1:1-chloromethacrylate and methylstyrene, Nippon Zeon) is one of the most popular positive to electron beam resists due to its sub-20-nm resolution, moderately high sensitivity and a dry etching resistance comparable to many novolac photoresists. However, high-resolution lift-off process with single ZEP520 resist layer doesn't exhibit good reliability. It is common that lift-off process fails because the material expected to stay on the substrate goes off together with those on top of ZEP520 resist. People usually attribute this phenomenon to the "scum" left from resist development stage which forms a spacer preventing later deposited material from adhering to the substrate surface. However, typically spacer formed by "scum" can be eliminated by improving the circulation of solvent (developer). Our experiments show that the nature of the spacer in ZEP520 development is a very thin (about 5 nm) layer of resist which can not be dissolved in regular ZEP520 developer.

A multilayer resist system is used to investigate the ZEP520 residual, as shown in Fig. 1. The multilayer is composed of a top e-beam resist layer, a hard etching mask layer, and a bottom ZEP520 layer. By modulating the dose of e-beam irradiation, a hard mask window is opened for removing underneath ZEP520 resist with oxygen plasma while the rest of fully exposed ZEP520 can be intact. The followed ZEP520 development reveals a thin layer of ZEP520 residual together with a clear step at the boundary to the zone previously etched by oxygen plasma, as shown in Fig. 2. The existence of the step proves the resist residual is not the result of "scum" re-deposition. Instead, it could be a layer of insoluble resist.

The origin and the properties of this insoluble residual will be discussed in detail.

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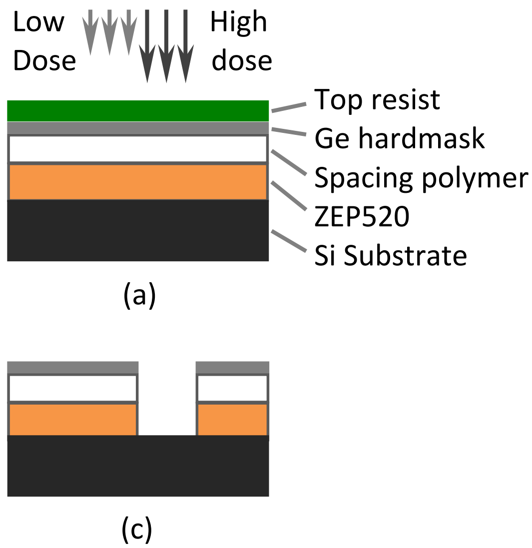

Figure 1: Process flow for sample preparation. (a) e-beam exposure on top resist layer; (b) Top resist area received high dose exposure is dissolved after development; (c) Transfer pattern from top resist to Ge mask and then to the rest of polymer layers by oxygen reactive ion etch; (d) ZEP520 resist received low dose exposure is dissolved after the second development process.

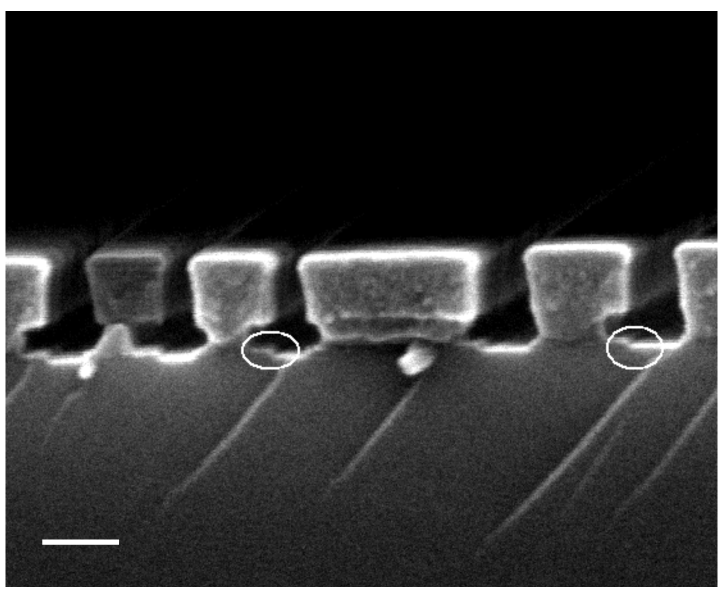

Figure 2: Cross-section SEM micrograph of a developed hard mask-ZEP520 multilayer. The steps indicated in the circles clearly reveal the existence of insoluble ZEP520 residual layer. The scale bar is 100 nm.