Application of magnetic neutral loop discharge plasma in deep quartz and silicon etching process for MEMS/NEMS devices fabrication

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Recently, deep quartz etching technologies to realize micro-opto-electromechanical systems (MOEMS) devices are required. And, silicon deep etching technology is also important. We report on the development of a novel etching system which micro and nano - electromechanical systems (MEMS/NEMS). Etching of quartz and silicon with one chamber using the newly NLD apparatus. The effective plasma production of the NLD method causes a low electron-temperature and high-density plasma in a low-pressure region below 1 Pa. This is one of the characteristics of the NLD plasma. The other important characteristic is controllability for uniform etching by changing the magnetic coil current radially and vertically [1,2]. A schematic of the NLD etching system is shown in Fig.1. Figure 2 shows the etching process flow, (a) KMPR (KAYAKU MICROCHEM Co.) or EB resist coating, (b) lithography, (c) NLD etching, respectively. KMPR has a same performance to a SU-8, and it is superior to SU-8 at the adhesion and crack on the silicon wafer, which were problems. Figure 3 shows KMPR pattern on the quartz substrate. The film thickness of KMPR was 50 um. Figure 4 shows SEM images of quartz deep etching profile after

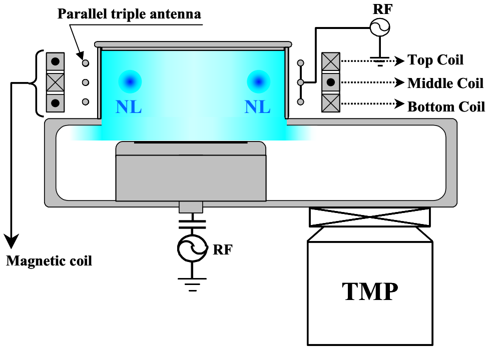

Fig. 1. NLD plasma etching apparatus.

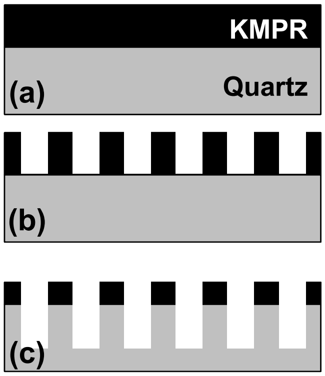

Fig.2. Fabrication process flow.

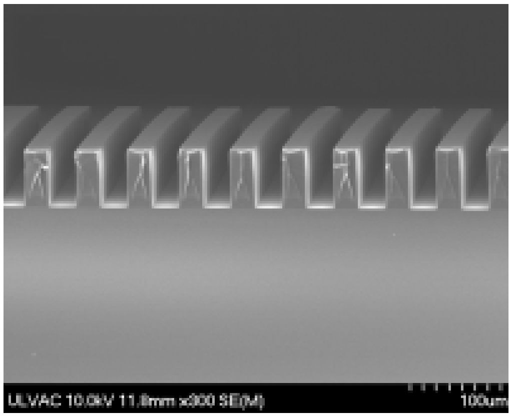

Fig.3. KMPR pattern on the quartz substrate.

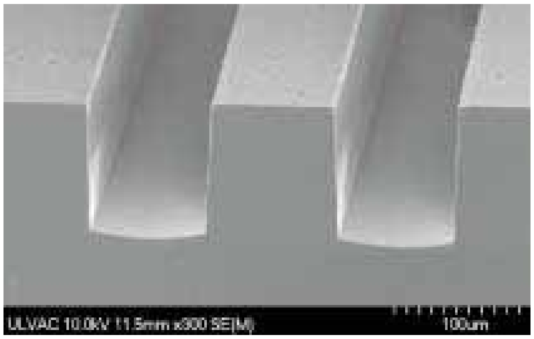

Fig. 4. Quartz deep trench etching

resist removal. We have succeeded in achieving the world’s first smooth and vertical deep etching of crystal to a depth of 125 um and at a rate of 1.2 um/min., further enhancing the glass etching performance. And next, case of nano etching for nano-device fabrication, lithography target dimensions are below the 100 nm realm, ArF or EB (electron beam) lithography are considered to be a promising technique. However, these resists have poor etching resistance, which brings on low mask selectivity and results in striation or pitting by resist degradation. This is a serious problem in a nano device fabrication, for example DNA or proteins sorting chip [3]. Figure 5 shows a nano-hole structure made of a quartz plate employing an EB (ZEP-520) lithography and a NLD etching. The diameter, depth of the hole and the aspect ratio were 40 nm, 800 nm, and 20, respectively.

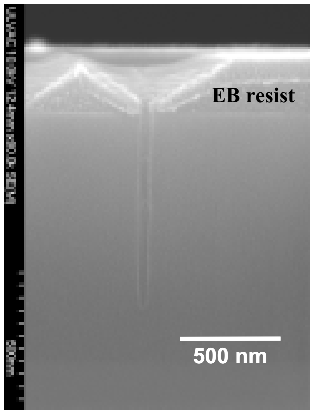

Fig.5. A nano-hole

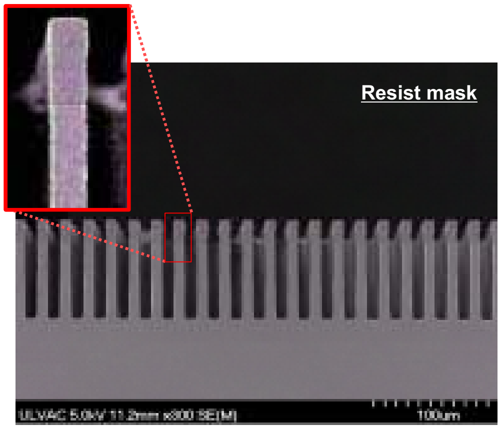

Fig. 6. Silicon deep trench etching

And finally, we have developed a new etching system for MEMS and NEMS application. This system provides combined plasma of NLD and a kind of capacitive coupled plasma (CCP), which is named as NLD-Si plasma. Using this system, deep silicon etching is capable even if fluorocarbon gases are not fed in the etching process. So this system is using our original technology. Silicon deep etching was carried out with resist mask in the NLD-Si plasma modulation, in which the electrodes were timely modulated for etching and deposition at a substrate temperature region above -10 ～ 30 ℃. The selectivity of 300 or more was obtained for resist mask. The etch rate was about 20 um/min when SF_6 / Ar was fed. Typically, the depth of 100 um with the line width of 10 um was anisotropically etched by the electrode modulation method in the NLD-Si plasma shown in fig.6, in which cleaning step was not necessitated. Thus, even if the fluorocarbon gas were not used, high selectivity and anisotropic deep silicon etching was achieved. Using NLD-Si system, vertical profile was successfully fabricated. This is the novelty silicon deep etching system for silicon-MEMS devices. The NLD-Si etching system is expected to be new de-facto-standard tool for R&D and mass production of current and next-generation MEMS/NEMS.

References

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