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Surface Cleaning of (100) n-Ge by H_2O_2 Aqueous Solution

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[Introduction] Surface cleaning of any semiconductors to remove contaminants is of fundamental importance for improving device performance and reliability. Unlike Si technology, which RCA clean method has been well established, effective Ge surface cleaning method is still under development.[1] H_2O_2-based solution can effectively remove particles chemically bonded to the surface by oxidizing the surface, while deteriorated surface roughness was reported previously[2]. In this study, we report that although the surface roughness increased initially, but then decreased when (100) n-Ge wafer was cleaned by H_2O_2 aqueous solution. We attributed the increase of initial rms to the effect of external surface contaminants but not intrinsic properties of (100) surface.

[Experimental] As-received (100) n-Ge wafer was cleaned by H_2O_2 aqueous solution as a function of dipping time. The surface roughness evolution was analyzed by atomic force spectroscopy (AFM) imaging with at least 3 different positions for each sample. Meanwhile, effect of cleaning conditions on the roughness evolution including temperature (23°C, 53°C and 73°C), incorporation of HCl into the solution, and volume ratio of H_2O_2/DIW(1/100, 1/500 and 1/10000) was also investigated.

[Results and Discussion] Fig. 1 shows the root mean square (rms) roughness of n-Ge (100) surface in the area of 1×1 um^2 as a function of immersion time in the H_2O_2/DIW solution (fixed volume ratio of H_2O_2/DIW: 1/100) at room temperature. The rms value was observed to be substantially increased initially, but then decreased gradually with increased cleaning time. Correspondingly, AFM topography also images a "jagged" then "smoothened" surface evolution. Meanwhile, similar small rms was also observed when clean atomically flat surface was dipped into the same H_2O_2 solution for 5min (no contamination). Such result indicates the initial rms increase ("jagged" surface) should not be the intrinsic property of (100) surface, therefore we attributed it to the effect of external surface contaminants. The contaminants at the wafer surface will be "micro-masks", and influence the oxidation and etching behavior of Ge in the H_2O_2 aqueous solution, thus surface roughness and morphology evolution (**Fig. 2**). Complete removal of contaminants relies on the critical etching depth (L) of the underneath Ge surface**,** which was influenced by cleaning conditions. **Fig. 3** shows that three approaches can influence the rms evolution: (i). by elevating the cleaning temperature; (ii). HCl incorporation into the H_2O_2 aqueous solution (SC-2 solution in Si industry); (iii). by diluting the oxidant concentration. The current results indicate that clean Ge n(100) surface with small rms roughness is feasible practically.

[Conclusion] A behavior of rms increase initially but decrease gradually of (100) n-Ge surface was observed, and the initial rms increase was attributed to the effect of surface contaminant "micor-masks".

[References] [1]. W.F. Zhang et al, IEEE SISC, 7-10, (2013); [2] J. Kim et al, ECS Transactions, 1(3), 214-219, (2005).

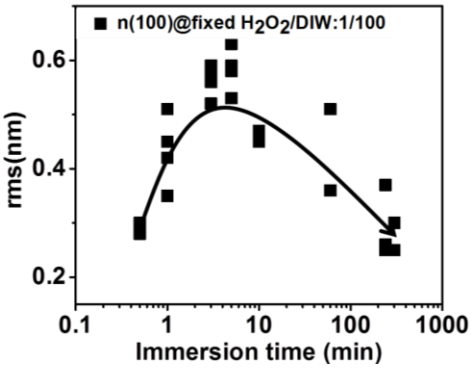

Fig. 1 Surface roughness (rms) evolution as a function of dipping time at fixed H_2O_2/DIW volume ratio (1/100).

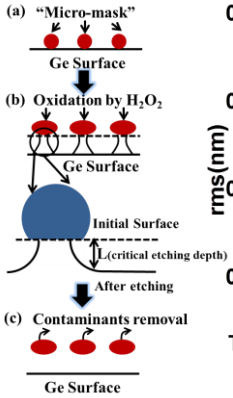

Fig. 2 "Micro-mask" mechanism proposed.

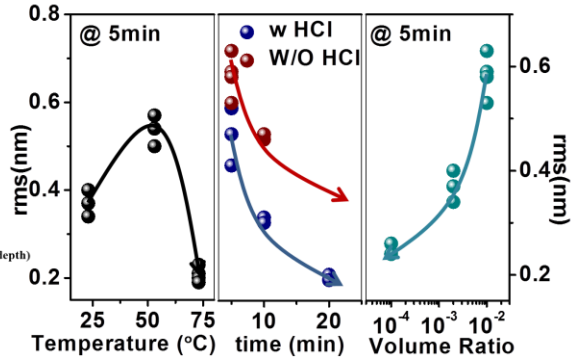

Fig. 3 Effect of cleaning conditions on the rms evolution. (left) temperature;(middle) with 0.1% HCl incorporation; (right) volume ratio.