Quasi-ALE process transfer from lab to 300mm line and its optimisation

Jenefa Kannan[1], Matthias Rudolph[1], Reza Jafari Jam[2], Amin Karimi[2], Dmitry Suyatin[2], and Jonas Sundqvist[2]

Atomic layer etching (ALE) has found its place in advancing technologies as chip sizes continue to shrink and pitch sizes get smaller. The ALE process offers several advantages over conventional reactive ion etching (RIE) such as better directionality, uniformity, selectivity and damage free surface after etching [1,2]. A self-limited removal of material with minimal damage to the surface requires a good control over every step of the ALE process [3]. Quasi atomic layer etching (QALE) is defined as a process when more than one mono-layer of the material is etched per cycle. Surface treatment, Control of ion energies and appropriate evacuation of the chemical component (Cl_2) is necessary to control the etch rate per cycle and achieve etch saturation in a cycle sweep.

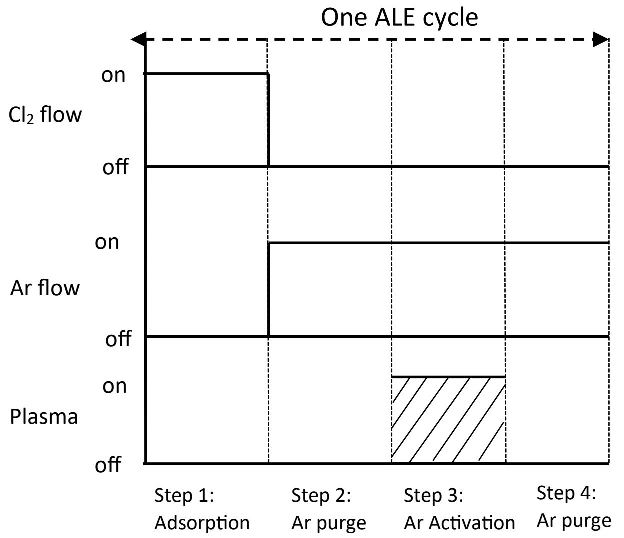

Figure 1: Sequence of the aSi ALE process

In our work, we have conducted in-depth studies to set up a molecular QALE process as seen in Figure 1 at our 300 mm facility in an inductively coupled plasma (ICP); decoupled plasma source (DPS) AMAT chamber on 350 nm amorphous Silicon (aSi) which was deposited on 12" blanket wafers. First, experiments were conducted to establish the bias power and pressure window. After this step, Ar sputter threshold for amorphous Silicon was determined. This was used as baseline to setup a cyclic process where the EPC was determined over low ion energies by optimising the bias power and activation time during exposure to Ar plasma. Damage or roughness caused to the layer being etched severely degrades device performance with decreasing dimensions [4]. Hence, to investigate the same, an Ellipsometer model was developed to understand the composition and thickness of this rough layer of the aSi surface post QALE etch.

Thickness of the rough layer was evaluated over increasing number of cycles. The EPC for different Ar activation times at bias power 25 W is shown in Figure 2. The thickness of the rough layer at the end of the cycles is seen in Figure 3. We observed that the Ar activation time and no. of cycles have an influence on the thickness of the rough layer after etching.

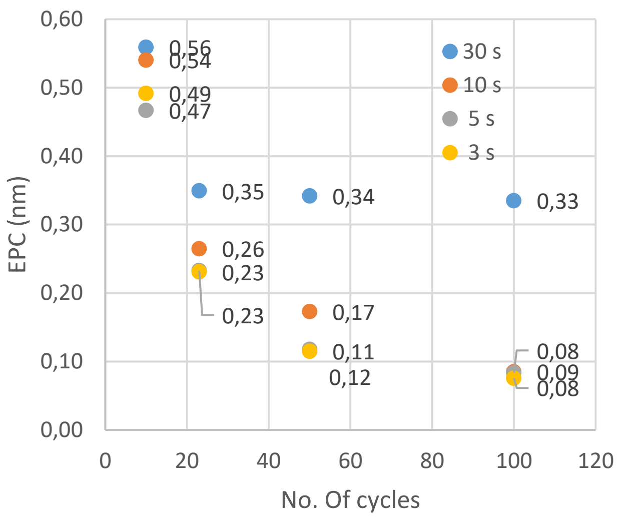

Figure 2. EPC over cycle sweep for Ar plasma at 25W for different Ar activation time

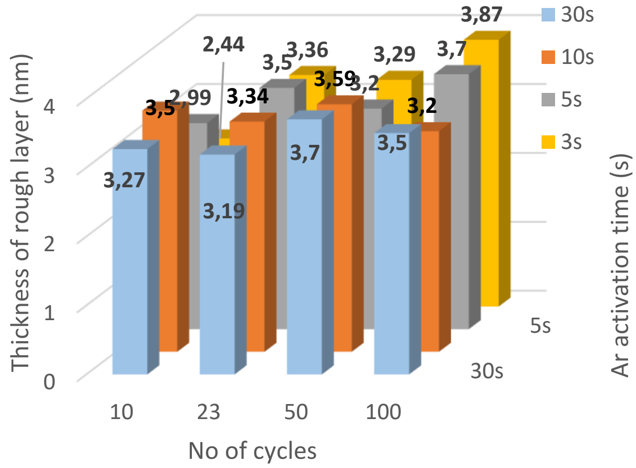

Figure 3. Thickness of rough layer vs. no of cycles and Ar activation time

In this work we investigate the factors and challenges that need to be taken into consideration while transferring the ALE process from lab to fab.In general, our work highlights the importance of control of every step in QALE for effective transfer and commercial viability in a 300mm line.

References:

1. D.S. Kim, J.B. Kim, W. Da Ahn, J.H. Choe, J.S. Kim, E.S. Jung, S.G. Pyo, Atomic Layer Etching Applications in Nano-Semiconductor Device Fabrication, Electron. Mater. Lett. 19 (2023) 424–441. https://doi.org/10.1007/s13391-023-00409-4.
2. S.D. Athavale, D.J. Economou, Realization of atomic layer etching of silicon, Journal of Vacuum Science & Technology B: Microelectronics and Nanometer Structures Processing, Measurement, and Phenomena 14 (1996) 3702–3705. https://doi.org/10.1116/1.588651.
3. Khan, S. A., Suyatin, D. B., Sundqvist, J., Graczyk, M., Junige, M., Kauppinen, C., Kvennefors, A., Huffman, M., & Maximov, I. (2018). High-Definition Nanoimprint Stamp Fabrication by Atomic Layer Etching. *ACS Applied Nano Materials*, *1*(6), 2476-2482. https://doi.org/10.1021/acsanm.8b00509
4. J.R. Vella, D.B. Graves, 2023. Near-surface damage and mixing in Si-Cl2-Ar atomic layer etching processes: Insights from molecular dynamics simulations. Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films 41, 042601. https://doi.org/10.1116/6.0002719