Growing transition metal dichalcogenides into industrial reactors, achievements and remaining challenges after processing more than thousands 300mm wafers

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Abstract
Intensive studies are ongoing to grow Transition metal dichalcogenides (TMDC) such as WS2, MoS2, WSe2 as 2D channel material for building competitive and reliable ultra-scaled logic devices. Several years ago, imec has adapted 200 and 300 mm cross flow epitaxial reactors to growth TMDC [1,2], either on template like sapphire or directly on amorphous gate or sacrificial dielectrics, using metal organic chemical vapor deposition (MOCVD), a technique compatible with industrial reactors.
In this presentation, we report on some of the learnings obtained after processing more than 1000 runs on each reactor. After describing the basic MOCVD processes used to control the tool and process along this development period, we share on safety and update on studies carried out to improve the tool and process stability and variability [3]. We illustrate the maturity of the process and material with a selection of results obtained on lab devices and 300 mm fab lots [4,5,6], and identify some remaining tool/process challenges to grow high quality TMDC in industrial tools.

References

[1] imec press release, 2018 IEEE IEDM (Imec reports for the first-time direct growth of 2D materials on 300mm wafers (imec-int.com))
[2] Matty Caymax & al., SSDM, D-1-03, 2019
[3] Yuanyuan Shi & al. ACS nano 15 (6). 9482-9494, 2021
[4] Inge Asselberghs & al. IEDM, 40.2.1-40.2.4, 2020
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Figures

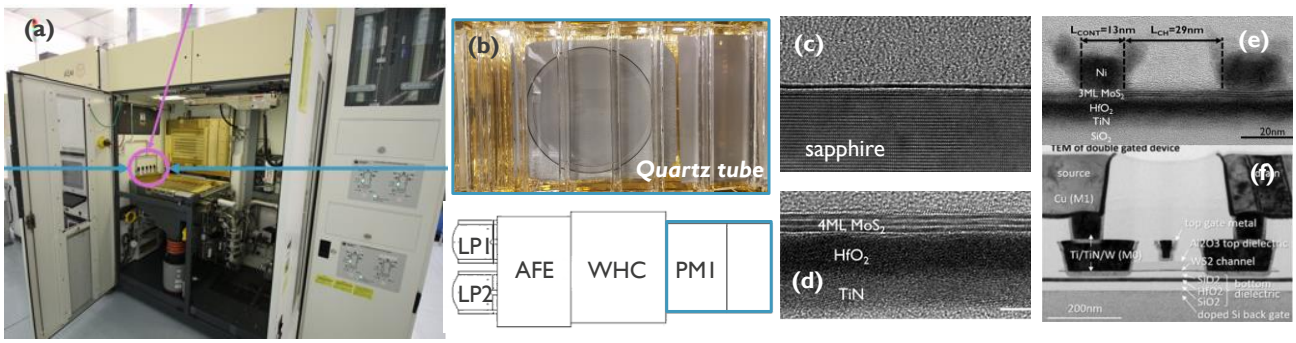

Figure 1: (a) tool mainframe, (b) cross-flow reactor and layout, growth on (c) either sapphire aiming a subsequent transfer to the final substrate or (d) directly on amorphous dielectric, either the gate dielectric or a sacrificial material to pursue the integration on same substrate. Cross section of lab (e) and fab (f) devices.