Master of Science HES-SO in Life Sciences

Plasma-Enhanced Atomic Layer Deposition with microwave plasma sources in a novel deposition equipment

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CHEMICAL DEVELOPMENT & PRODUCTION

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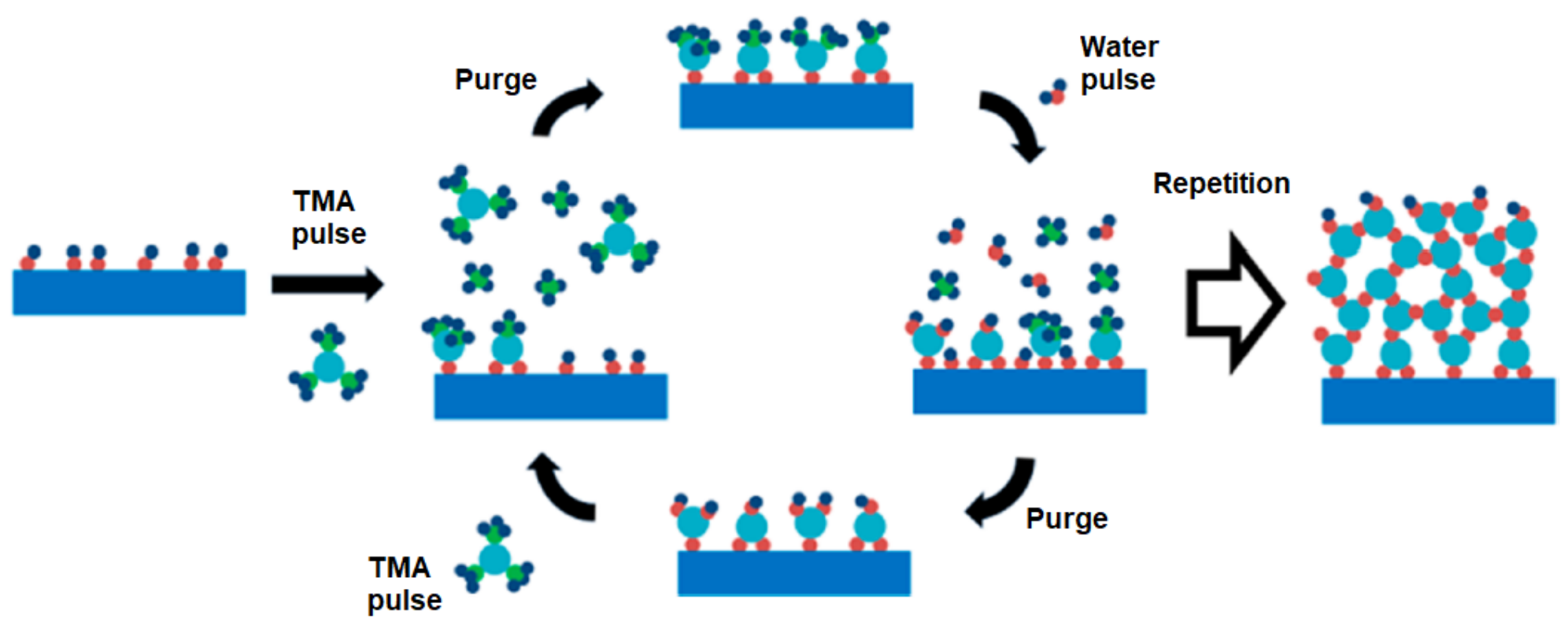
DESCRIPTION

In a novel deposition equipment developed by Swiss Cluster AG, the Swiss Cluster-1 (SC-1), microwave plasma-enhanced atomic layer deposition (PEALD) was investigated and developed in order to extend and better understand the potentialities of this machine and of the microwave plasma sources in the thin films fabrication. The thin films investigated were aluminum oxide, deposited through trimethylaluminum (TMA) and water plasma, and titanium nitride, produced through tetrakis(dimethylamido)titanium (TDMAT) and nitrogen plasma. In order to understand the advantages and disadvantages of the microwave PEALD, Al_2O_3 was first investigated and deposited through atomic layer deposition (ALD), with TMA and water, in this way it was possible to have a direct comparison between the two deposition techniques. The Al_2O_3 and TiN depositions were performed on silicon wafer substrate, the aluminum oxide (in both ALD and PEALD process) was deposited with a temperature gradient from room temperature to 300°C, while the titanium nitride at a homogeneous temperature of 180°C. The temperature gradient through the silicon wafer was possible thanks to a heating system called «temperature gradient stage» (TGS), this system is inside the sample holder and allow a precise heating and temperature control of the substrate.

All the deposited thin films were analyzed through scanning electron microscope (SEM), X-ray reflectivity (XRR) and elastic recoil detection analysis (ERDA) in order to characterize their physical-chemical properties, as the thickness, and consequently the growth per cycle (GPC), the density, the surface roughness and the elemental composition. These parameters were used in comparison with the literatures for understand the quality of the thin films produced and in the case of the Al_2O_3, also the differences and advantages or disadvantages of the PEALD process compare to the ALD.



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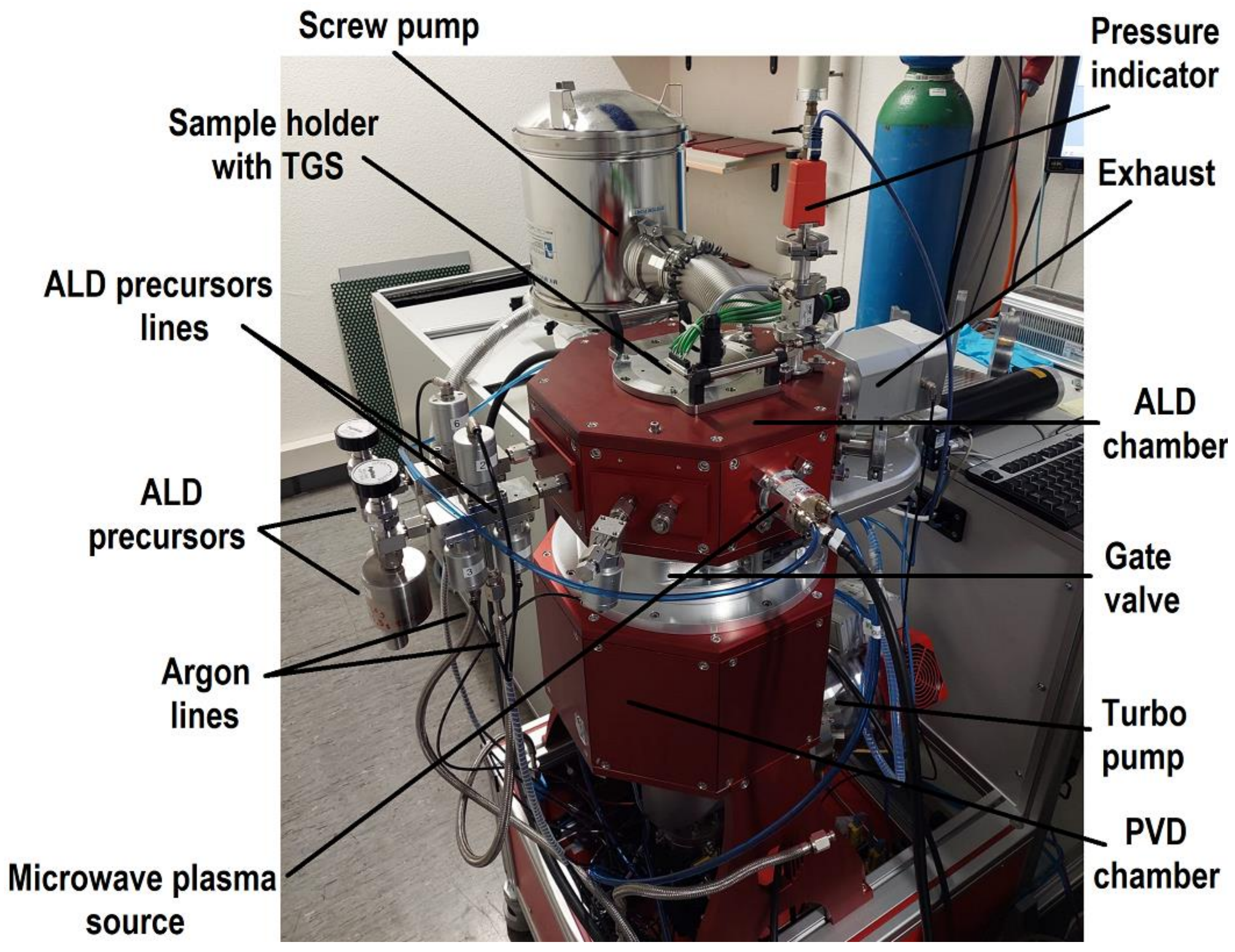
OBJECTIVES

The aim of this study is to develop the microwave plasma-enhanced atomic layer deposition in a novel deposition equipment, the SC-1, in order to extend and better understand the potentialities of this machine but also to better understand the potentialities of microwave plasma in the thin film fabrication. To achieves these results and to have a direct comparison between the ALD and PEALD process, three different types of films will be prepared and characterized as previously described.

- ALD thin film of Al_2O_3 from TMA and water.
- PEALD thin film of Al_2O_3 from TMA and water plasma.
- PEALD thin film of TiN from TDMAT and N_2 plasma.

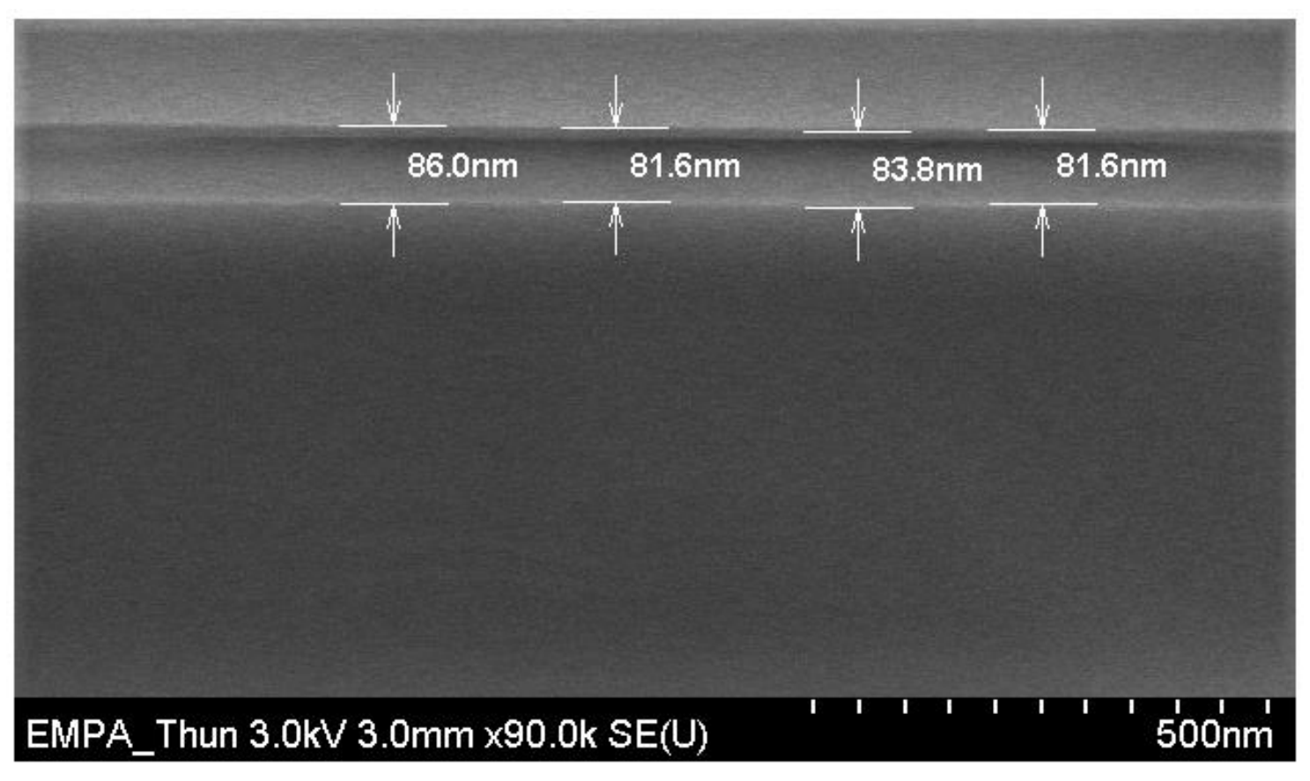
RESULTS

The results obtained from the ALD Al_2O_3 show a maximum growth per cycle and density at 200°C, with a values of 1.06±0.05 Å/cycle and 3.24±0.2 g/cm^3 , both comparable with the literature. The thin film produced is very smooth with a surface roughness of 0.19±0.1 nm, the impurities content is less than the literature at lower deposition temperature and comparable at the higher temperatures. All of these results show a dense, smooth and high pure Al_2O_3 thin film.



The Al_2O_3 produced through microwave PEALD shows a different trend in the GPC distribution over the deposition temperature, where the maximum growth per cycle was found at 110°C, with a value of 1.77±0.09 Å/cycle. The results also show a maximum density of 3.61±0.2 g/cm^3 at 300°C, a surface roughness of 0.3±0.1 nm, and a lower impurities content, similar to the ALD film. All the results obtained demonstrate that the aluminum oxide deposited through microwave PEALD is not more or less pure or smooth than the film produced via ALD but it is instead denser and thicker, showing that the plasma process, in the SC-1, is the most advantageous in the Al_2O_3 thin films fabrication.

The titanium nitride deposition shows a maximum GPC of 0.99±0.03 Å/cycle, a maximum density of 4.29±0.2 g/cm^3 and a surface roughness of 1.8±0.1 nm. These results are comparable with the literature but they are all significantly inhomogeneous distributed to the film, showing that more investigation and improvement are needed in the PEALD process. In any case this deposition demonstrate the possibility to produce in the SC-1 TiN through TDMAT and nitrogen plasma.



CONCLUSION

The aluminum oxide produced through microwave PEALD in the SC-1 shows a higher density and growth per cycle compare to the Al_2O_3 produced via ALD process. There is not instead a significant improvement in the impurities content and surface roughness, where in both techniques, a smooth and low impurities content thin film was produced. Considering the results obtained it is possible to state that the use of the microwave PEALD in the Al_2O_3 production through the SC-1 is more advantageous than the ALD process, as it is possible to produce with the same deposition parameters a thicker and denser thin film.

Regarding the titanium nitride deposition, the results shown the possibilities to produce this thin film in the SC-1 with TDMAT and N_2 plasma, however, further investigations are needed in order to improve the deposition process and allow the possibilities to produce an high quality TiN thin film.