Surface Termination of Oxide Single Crystal Substrates by Laser Annealing

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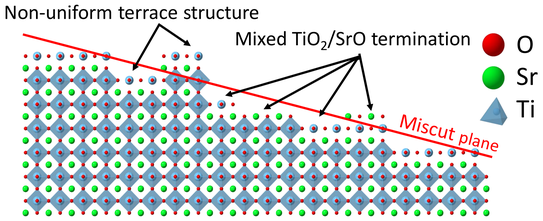
Introduction

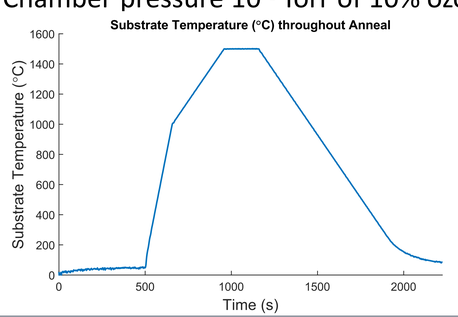
- As-received substrates can exhibit non-uniform terrace structures and mixed surface terminations



- Atomically sharp interfaces and chemically homogenous terraces are required for high quality film growth and observation of interface phenomena[1,2,3]
- Currently substrates are etched and annealed at around 1000 °C to produce a uniform terrace structure with a single surface termination.[2] These procedures are *ex situ* and can leave behind chemical residue.[4]
- *In situ* laser annealing in an environment of 10^{-2} Torr of O_2 has been shown to be a chemical-free alternative to these conventional substrate preparation methods.[5]

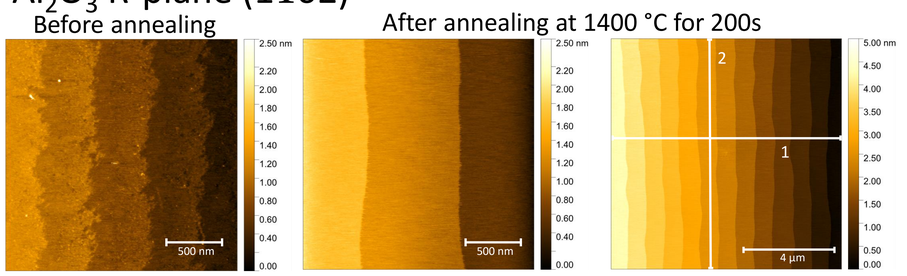
Experimental

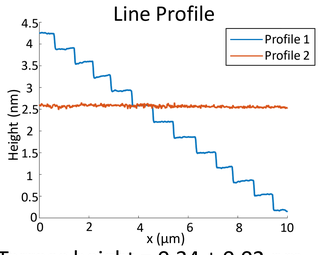
- Substrates were annealed at high temperatures for 200 seconds using the 10.6 µm laser substrate heater in the PARADIM MBE chamber
- Chamber pressure 10^{-6} Torr of 10% ozone



Results

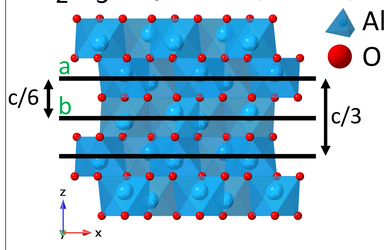
Al_2O_3 R-plane ($1\bar{1}02$)

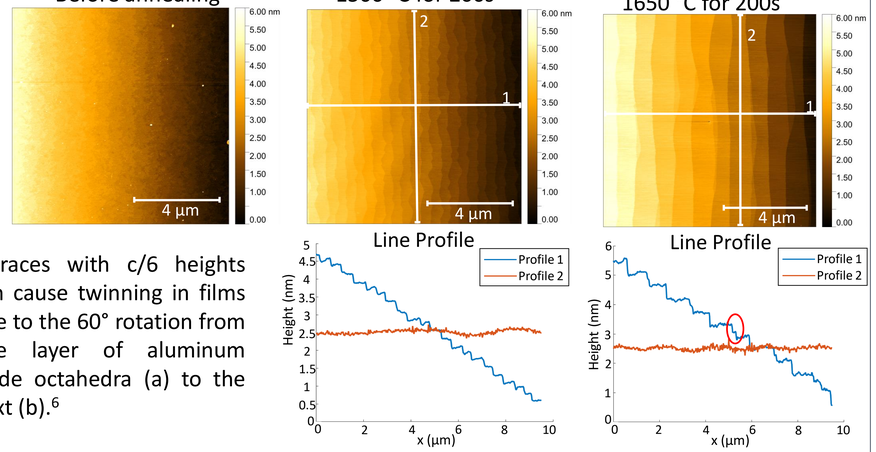


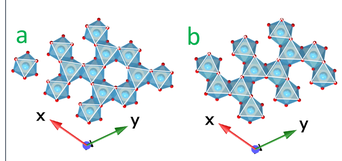


Terrace height = 0.34 ± 0.02 nm

Al_2O_3 C-plane (0001)

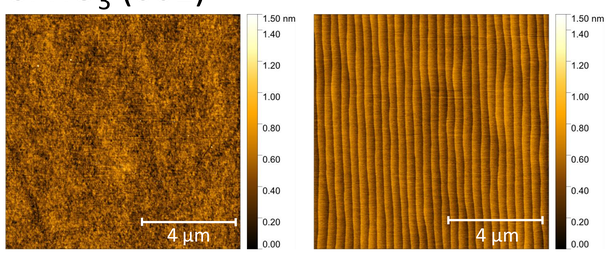




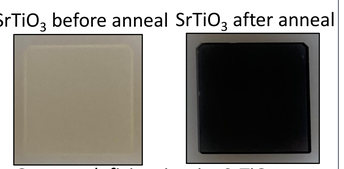


Terraces with c/6 heights can cause twinning in films due to the 60° rotation from one layer of aluminum oxide octahedra (a) to the next (b).[6]

$SrTiO_3$ (001)



Terrace height = 0.41 ± 0.02 nm

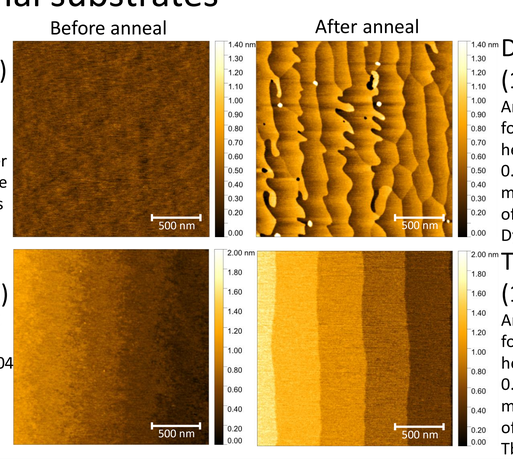


Oxygen deficiencies in $SrTiO_3$ are responsible for the color change and electrical conduction.[7] Further optimization of the annealing recipe is necessary to produce electrically insulating substrates

Additional substrates

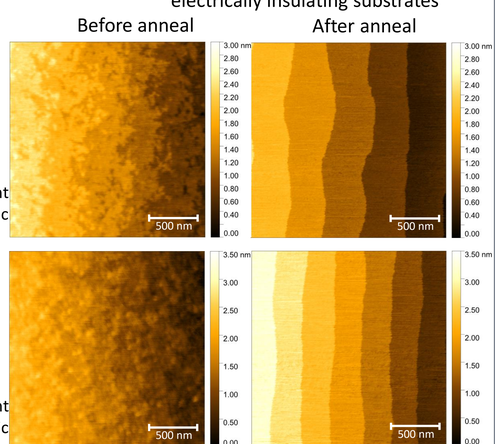
Al_2O_3 M-plane ($10\bar{1}0$)
Anneal at 1300 °C for 200s. Multiple terrace heights means that further optimization of the annealing recipe is necessary.

Al_2O_3 A-plane ($11\bar{2}0$)
Anneal at 1400 °C for 200s. Terrace height = 0.27 ± 0.04 nm. This matches the A-plane interplanar spacing.



$DyScO_3$ (110)
Anneal at 1400 °C for 200s. Terrace height = 0.39 ± 0.02 nm. This matches the height of the pseudocubic $DyScO_3$ unit cell.

$TbScO_3$ (110)
Anneal at 1470 °C for 200s. Terrace height = 0.38 ± 0.03 nm. This matches the height of the pseudocubic $TbScO_3$ unit cell.



Conclusions

- Uniform terrace structures on oxide substrates appropriate for film growth can be achieved by laser annealing in a background pressure of 10^{-6} Torr of 10% ozone, an accessible oxidation environment for the PARADIM MBE
- The annealing parameters were determined for R-plane Al_2O_3, A-plane Al_2O_3, $DyScO_3$, and $TbScO_3$
- Further work is necessary to achieve a single terrace height on M-plane Al_2O_3, to produce a complete c/3 terrace height on C-plane Al_2O_3, and to minimize the effects of reduction during the annealing of $SrTiO_3$

Acknowledgments

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