Thermal processing of high-K materials thermodynamics and kinetics

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High-K requirements
RTP speed and kinetics

High-K dielectric materials for CMOS must meet the process requirements of standard CMOS processing. Thermal processes play a key role in CMOS processing. The Source/Drain implant activation anneal~~s~~ sets the temperature budget. There is a strong drive to look for amorphous high-K films to replace the (amorphous) silicon oxide thermal gates. However, phase separation and crystallisation of the high-K films severely limits the choice of materials. This paper will compare the role of RTP Processing conditions and the effect on the temperature stability of the high-K films. Appropriate anneal conditions may be developed to create optimal S/D dopant activation while suppressing phase separation and crystallisation.

Figure 1 illustrates the relationship between high temperature soak time and crystallization temperature and for various mol. % Al_2O_3 – metal oxide films. The alumina rich film meets standard CMOS thermal process requirements based on crystallization studies.

Phase separation in gate oxides gives rise to electrical trapping and should therefore be avoided. Careful analysis of the FTIRS data in Figure 2 indicates possible phase segregation due to anneal processing of the Al-Zr mixed oxide material.

Post deposition anneal
RTP ambient and thermodynamics

Current high-K deposition tools (ALCVD and MOCVD) operate at low deposition temperatures. Post deposition anneals are required to improve high-K film and interface quality. Meanwhile, the film integrity must be maintained. Again, proper thermal processing plays a key role. Choosing the appropriate processing ambient that meets the thermodynamic stability limits of the gate stack, the high-K films and the interfacial silicon oxide layer in particular, is essential. The SEM of Figure 3 shows the detrimental effect of nitrogen anneal on Zr-oxide. Mixed Al-Zr-oxide high-K stacks however demonstrate compatibility with required anneal conditions.

The paper will highlight the role of ambient in post deposition anneal conditions for selected materials.

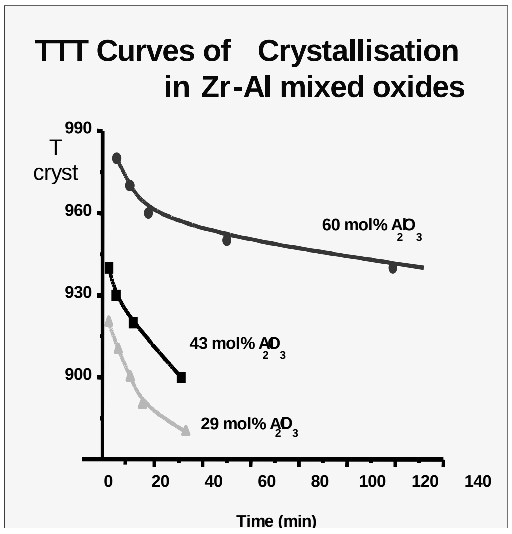

Fig. 1. Crystallization temperature plotted as a function of anneal soak time for three $AlZrO_x$ compositions.

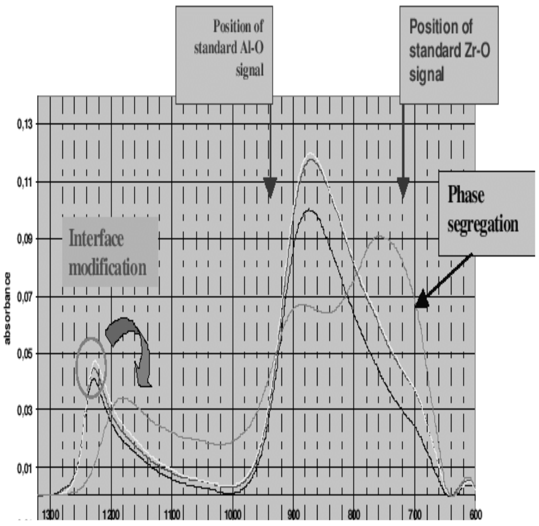

Fig. 2. ATR-FT-IR spectral changes of $AlZrO_x$ on RTO after anneal in nitrogen.

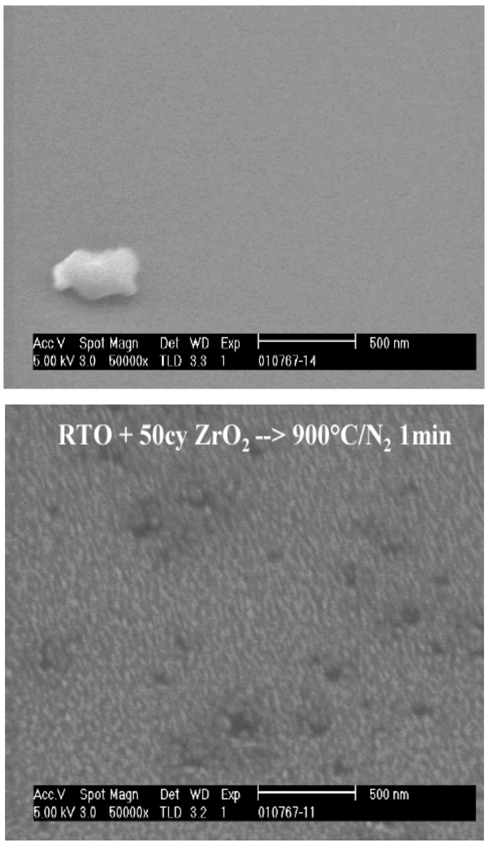

Fig -3- SEM surface topography of 900 °C annealed $AlZrO_x$ (top) and ZrO_2 (bottom) on RTO oxide.