The Atomic Alloying Nano Laminate by ALCVD for MIM CAP within IC BEOL and Metal Gate oxide candidate for EOT < 9 Angstrom

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With the fast development of RF and nanoscaling devices, a strong need of decoupling capacitor within the IC BEOL led to the development of high k material and interface layers used as bottom and top electrode plate. According to the versatile applications of CMOS, RF CMOS, BiCMOS/SiGe HBT, different operating voltage are used and therefore several specifications are defined for each application.
The known high k materials in the art are most of the time Ta_2O_5, nano laminate THO and more recently the nano laminate AHO are the most popular high k for capacitor and for metal gate oxide.

Development effort is undertaken for the purpose of manufacturing MIM CAP of capacitance above 5 fF/μm^2 with leakage density current of 10^{-7} A/cm^2 at the highest operating voltage of BiCMOS/HBT 5.5V and for getting the highest breakdown field. With the known high k materials and nano laminate, it is hard and almost impossible to get this level of performance.

In using the principle of alloys by the technique of ALCVD, a ratio of monolayers ML of Al_2O_3 and HfO_2 is fixed and in this such a way, we create $Hf_xAl_yO_z$. This principle is added to the nano laminate for developing the Atomic Alloying Nano Laminate "AANL" whose the number of interfaces is increased, without the polycrystalline phase of Hafnium oxide and in playing with the stoechiometry of each alloy film of the AANL. In working on the AANL, the films order and typical stoechiometry, an ML arrangement is found and this solution is based on the variation of each alloying film stoechiometry. The precursor sequence and the upper chemical bonding surface are the most important parameter in this scheme. Therefore, research effort is focused on the chemistry and new precursors with a few carbon and hydrogen impurities contamination in the as deposited films by ALCVD even for a low thermal budget of BEOL.

According to the experiments and the different runs, an interface of $Hf_xAl_yO_z$ gives the lowest leakage current and density to the standard interface layer TiN or to the low k adhesion layer WNC rather the Al_2O_3 layer in nano laminate AHO or ATO with 2 magnitudes of difference in leakage and with a higher quality factor. This electrical behavior seems repeatable die to die, wafer to wafer and run to run. As the comparison run shows, all AANL stoechiometry and films arrangement have better performance than AHO and the high k of reference Al_2O_3. The AANL is still amorphous up until 1000^o C.

With the level of interest in this new material AANL, the metal gate damascene become a challenge wherein the AANL could be a good candidate. The development of specific precursor is ongoing for enhancing the behavior of AANL interfaces and for avoiding the Cl impact within each alloying film by the using of non-chloride precursor and in choosing new ligands within precursor molecule for forming the combination of metal oxide with only one injection of H_2O or ozone. This effort will allow the formation of an ultra thin SiON of 0,3 nm at the interface with AANL which allow to get an EOT of 9 Angstrom after annealing at 600^oC according too to the scheme of metal gate integration. For the purpose of developing a specific AANL as candidate to the metal gate oxide, a new scheme of integration is developed for limiting the cross diffusion of oxygen and oxide formation on the Well: furthermore new kind of ALD process is ongoing for inhibiting the chemical SiO_x growth by new precursors and ALD cycle sequence and in limiting the thermal budget of the metal gate and gate oxide which is based on AANL with nitride interface to Well surface.

Fig 1 : leakage current of AANL1 of 10,5 nm as total thickness within MIM CAP area of $1mm^2$

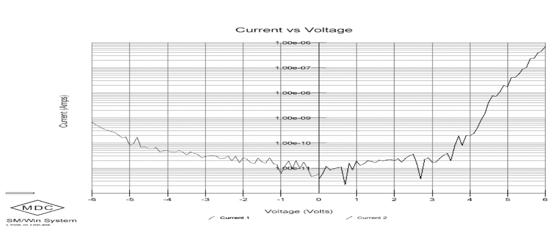
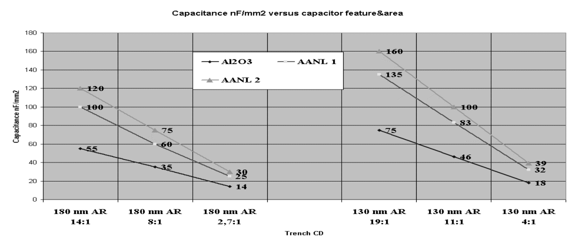


Fig 2: Capacitance per trench MIM capacitor CD and



comparison between Al_2O_3 - AANL stoechiometry 1 & 2
Fig 3: TZB test on trench MIM capacitor with high k material AANL 1 of 10,5 nm thickness

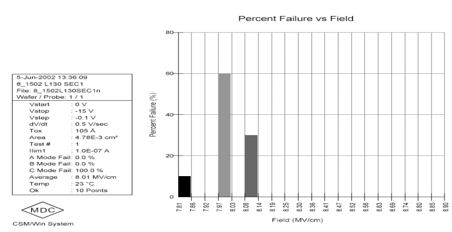


Fig 4: HRTEM with magnification of 400k of AANL of physically 3,6 nm on Si CZ