An innovative and flexible deposition technique to fill the gap between ALD and CVD

Fabien Piallat[1], Laetitia Bonnet[1], Julien Vitiello[1]

[1] *KOBUS, 611 rue Aristide Bergès, 38330 Montbonnot Saint Martin, France*

From the first transistor and until 2000, Chemical Vapor Deposition (CVD) was the only chemically enhanced deposition technique used for thin films deposition. Films with specific chemical composition have since emerged in the nanotechnology field. More recently, Atomic Layer Deposition (ALD) is investigated as a complementary method to CVD [1] for thin and well controlled layers. Indeed, films obtained by ALD are highly conformal (100%) whatever the substrate topography, but at the price of extremely low growth rate, making it not suitable for applications requiring thick layers (> 20 nm). In this perspective and to merge CVD and ALD advantages, the Fast Atomic Sequential Technique (F.A.S.T®) was developed.

Dedicated hardware solutions were found to allow a complete separation of the reactant and precursor until they meet right above the substrate, hence limiting the parasitic reactions and the necessity of purges to eliminate the excess of reactive species [2]. FAST tool can be used in continuous mode, in pulse-purge mode or in pulse only mode, as presented figure 1. Even though similar approaches were presented in the past and referred to “purge-less ALD” or “pulsed-CVD”, the novelty resides here in the possibility to process both CVD (figure 1 a), ALD (figure 1 b) and FAST (figure 1 c) in the same chamber. Moreover, the process window is now extended with a new parameter: the pulse position, i.e.; pulses can overlap for a CVD-like process or be well separated for ALD-like process.

Additionally, using a dedicated direct liquid injection system gives access to a broad type of precursors to be injected, thus allowing a wide range of materials to be deposited. For example, FAST technology was already used for the deposition of silicon, aluminium and zinc oxides, or silicon, titanium and tantalum nitrides. This presentation will be mainly focussed on the comparison of two of the most common oxide and nitride, i.e. silicon oxide and titanium nitride.

A detailed investigation of the deposition behaviour, growth rate (figure 2), activation energy, conformality (figure 4) and films properties will be presented for both materials deposited by the three techniques ALD, CVD and FAST. As presented in figure 3, the activation energy is more favourable in FAST mode than in the CVD one (30% higher). For a same deposition reaction, the substrate temperature can then be decreased in FAST process and thermally sensitive materials can be used as substrates. FAST layers conformality is at least three times greater than in CVD mode for high via aspect ratio as described in figure 4, while being 10 times faster than ALD. Advantages of each technique will be highlighted by the application to which they are the most suitable, as summarized in figure 5. For example the high growth rate of CVD enables thick layers for MEMS, the high conformality of ALD is suitable for nano-wires encapsulation, and the compromises of FAST makes it ideal for thick and conformal layers in TSV or photovoltaic devices.

[1] J. E. Crowell, J. Vac. Sci. Technol. A Vacuum, Surfaces, Film., vol. 21, no. 5, (2003)

[2] F. Piallat, J. Vitiello, J. Vac. Sci. Technol. B, Nanotechnol. Microelectron. Mater. Process. Meas. Phenom., vol. 34, no. 2, (2016)

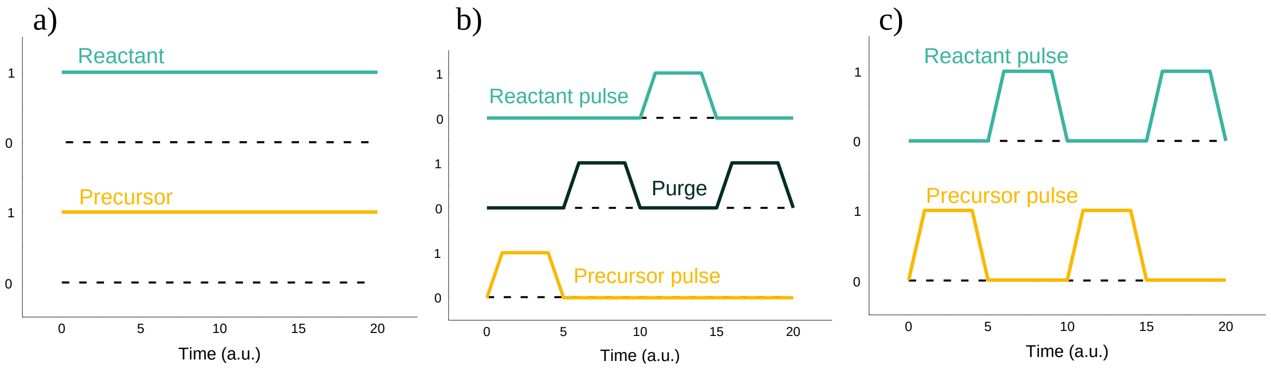

Figure 1. a) CVD mode with continuous flow of precursor and reactant gas, b) ALD mode with alternate pulses of precursor, purge and reactant; and c) FAST mode with pulsed injection of reactive species without purges.

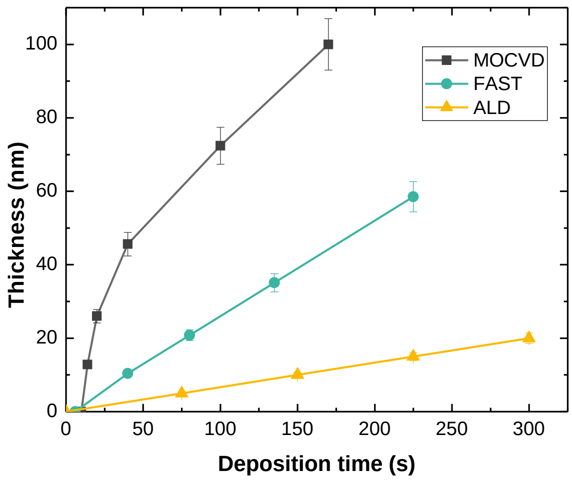

Figure 2. Evolution of layer thickness with deposition time by ALD, CVD and FAST.

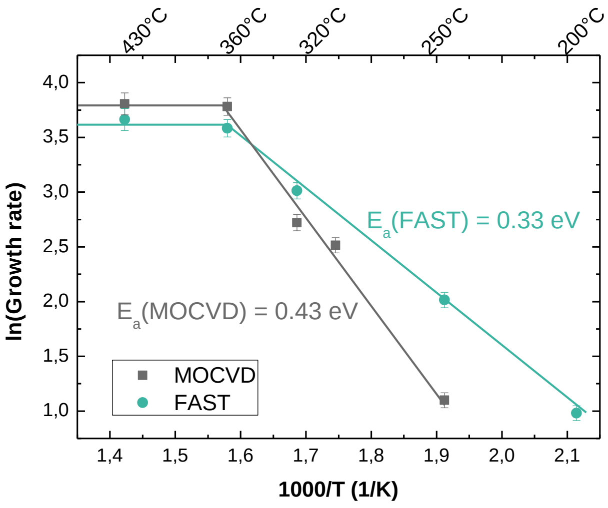

Figure 3. Arrhenius plot of TiN deposition by CVD and FAST techniques.

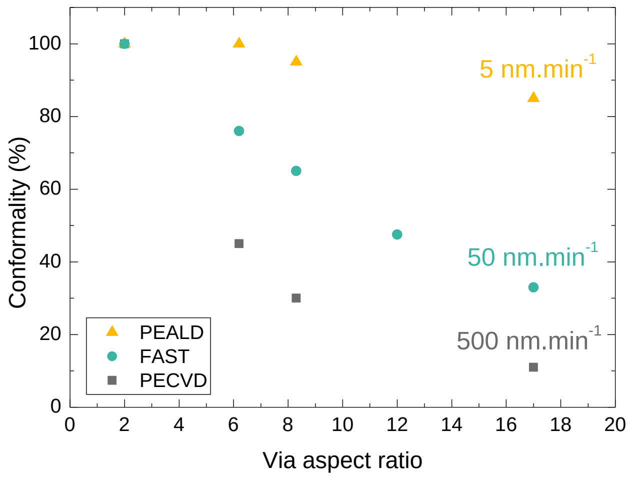

Figure 4. SiO_2 layer conformality evolution with via aspect ratio increase depending on the deposition mode

	ALD	FAST	CVD
Conformality	+++	++	-
Deposition rate	-	+	++
Minimum deposition temperature	++	++	-
Film properties	++	++	+

Figure 5. Pro and cons of the ALD, CVD and FAST deposition modes.