Recent developments in atomic scale processes for advanced quantum and nano-electronic device fabrication

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Over the past 20 years, the microelectronics industry has undergone numerous technological developments in fabrication strategies in order to sustain the constant miniaturization pace of integrated devices dictated by Moore's law. Nowadays, the fabrication of smaller devices involves an increasing number of embedded functionalities dedicated to on-board electronics in various consumer and production goods. The era of ultra-miniaturized device fabrication with dimensions scaling below 10 nm is currently on its way, enabled simultaneously by the introduction of exotic materials (eg rare earths or graphene), highly complex 3D architectures and advanced atomic-scale processes.

In this presentation, conventional miniaturization strategies will be reviewed in details based on examples taken from the literature, with special attention devoted to their strength and limitation in reaching the nanoscale size. The recent strategy developed at LTM laboratory in Grenoble and based on an original innovative selective thin film growth process will be described, to illustrate how thin films with atomic-scale control of both thickness and placement can be achieved, thanks to the assistance of a dedicated cold-plasma reactor.

Each process optimization requires a careful definition of various plasma parameters depending on numerous Plasma - Surface interaction mechanisms at play during growth. The impact of the relative contribution of both ionic and radical components within the plasma gas phase will be addressed to account for the very low pressure levels established in our conventional ICP-type plasma reactor. We will show that a very low partial pressure of precursor gas ensures a non-collisional plasma sheath in the vicinity of the substrate, which in turn enables a careful adjustment of the incident kinetic energy of the ion flux, hereby promoting growth selectivity. Several proofs of concept will be given for the self-placement of thin films as examples of such bottom-up selective growth processes and for the formation of self-aligned nano-dots of various materials and sizes by sequential infiltration.