Plasmas facing Semiconductors and Oxides: Key issues to control and tailor their Interaction

Maria Losurdo,
Marianna Ambrico, Gregorio Bottaro, Pio Capezzuto, M.M. Giangregorio, Alberto Sacchetti and Giovanni Bruno

Institute of Inorganic Methodologies and of Plasmas, IMIP-CNR, via Orabona 4, 70126 Bari, Italy

Because of operational versatility of plasmas (e.g. controlling species density and energy by tailoring plasma experimental parameters, namely, gas chemistry, pressure, excitation frequency and power and plasma configuration), they are efficient sources of a large variety of species suitable to activate surface reactions, and, hence, are usable in numerous applications related to materials growth and processing.

The major scientific theme of research for plasma processing of materials is the characterization and understanding of the processes at the plasma-material interface that control the properties of the material or structure that is ultimately produced. This research requires not only tools that characterize the plasma phase, but also surface-sensitive diagnostic able to monitor in real time the plasma-material interaction, and to assess the critical reactions and parameters that determine the ultimate characteristics and functionality of the materials and structures produced.

In this frame, although various optical probes are now available to investigate complexity of the plasma-material interaction, spectroscopic ellipsometry has been shown to be extremely versatile in detecting physical, chemical and electronic phenomena and modification for a large class of materials synthesised and processed via plasma. This is extremely important for nanomaterials, since a strong dependence of nanostructure, morphology, and composition of thin films on deposition methodology exists, which impacts on functionality of the nanostructure.

This contribution will present and discuss examples of the plasma assisted growth (MBE and MOCVD) and of the remote plasma processing of surfaces of a large variety of materials going from IV-IV semiconductors (e.g. Si-based materials and SiC) to III-V semiconductors (e.g. GaAs, and III-Nitrides InN, GaN) and finally to II-VI (e.g. ZnO) and oxides (e.g. TiO$_2$, Er$_2$O$_3$...). The purpose of this seminar is to show how real time spectroscopic ellipsometry has revealed some “thought misconception” and highlight how the knowledge gained about the chemistry governing the growth process is of specific value for understanding and further developing materials and their applications. The focus is on the interplay process-structure-property of semiconductors and multi-functional oxide thin films and on the importance of monitoring and tailoring chemical and electronic phenomena activated by plasma at surfaces and interfaces in controlling growth of materials and their final properties.

All those materials are facing “elementary” plasmas namely, H$_2$, O$_2$ and N$_2$ plasmas that activate their growth, surface passivation and cleaning. Data will show how the plasma activation can be used for tailoring the nanostructure of the materials reported above. Specifically for oxides, it will also be shown how low temperature remote plasma can be effective for improving nanostructural order, density and transparency for functional applications as coatings. Furthermore, it will be shown how spectroscopic ellipsometry can be used to optimize plasma conditions in order to activate the desired reaction at the surface.

This contribution is supported by the European 7FP project “NanoCharM” – Multifunctional NanoMaterials Characterization Exploiting Ellipsometry and Polarimetry”. To learn more about the project and the consortium partners, please visit www.nanocharm.org

References