ATOMIC Summary

August, 2016

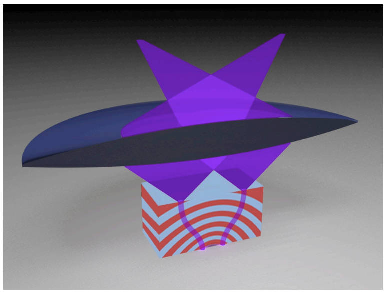

Figure 1- ATOMIC main target. The scheme shows how the combined use of bulk optics (blue element in the picture) with planar Hyperlenses could allow for a deep sub-wavelength imaging resolution in the VIS range.

ATOMIC, namely "**A**dvanced **T**ransformation **O**ptical **M**aterials for bio-**I**maging and light-**C**oncentration", is a project aiming at the development of novel compounds and fabrication techniques enabling a new class of artificial materials with unprecedented capabilities for a broad spectrum of possible applications including: i) ultra-resolution imaging (Planar Metamaterial Hyperlenses - PMHs) (see Fig.1); ii) enhanced energy harvesting (Light Concentrators – LCs); iii) efficient and integrated optical quantum sources; iv) ultra-fast tunable nanophotonic devices. The purposes of the project extended beyond the originally targeted goals embracing the investigation of the optical properties of alternative plasmonic compounds such as Al-doped and Ga-doped zinc oxide (belonging to the category of transparent conductive oxides -TCOs) plus titanium nitride and scandium nitride (being Transition Metal Nitrides - TMNs). These materials carry the potentials for overcoming all the major limitations typical of current nanophotonic modules such as: very limited tunability (here defined as the capability of changing the material's optical properties), high propagation losses, low heat resistance, and incompatibility with standard fabrication processes for low cost industrialised mass production. The choice of using alternative material platforms for the design and fabrication of optical devices allows us to arbitrarily engineered the way our structures react once struck by light; this was attained on a broad wavelength range and in an ultra-fast fashion.

The ATOMIC project produced a remarkable set of results spanning from materials science, to telecom applications including integrated quantum optics. Figure 2 gives a general overview of these achievements. More specifically:

Fig.2-a) Shows a schematics of the atomic structure for a new kind of oxygen depleted aluminum-doped zinc oxide synthesized and studied for the first time under the framework of the ATOMIC project. this material has been proved to overcome the typical tradeoff between magnitude and speed of an externally controlled change in the optical properties, also establishing new records in the nonlinearities of doped semiconductors.

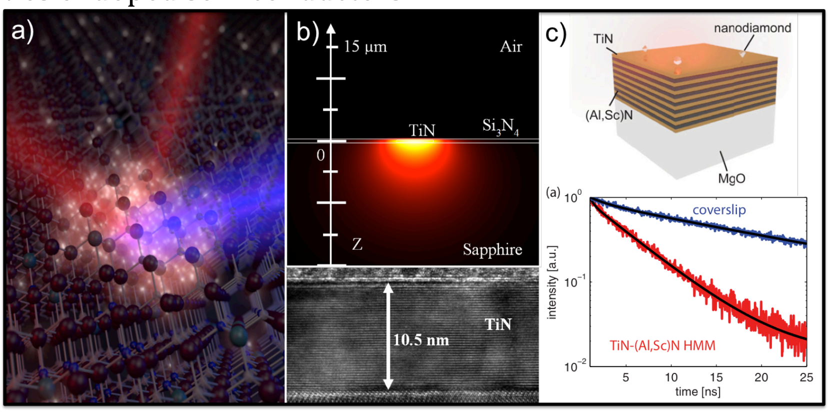

Figure 2- Fundamental results obtained along the development of the ATOMIC project.

Fig.2-b) With respect to the fabrication and characterization of ultra-thin (<10nm) metal-like films of heat-resistant materials, low-loss TiN-based plasmonic waveguides were fabricated and tested. The study was performed in a broad wavelength range including the telecom region thus making our interconnects fundamental components for future nanophotonic circuitry.
Fig.2-c) Towards the realization of multilayered PHMs and LCs, superlattices of TiN/ScN were fabricated by metal/dielectric deposition of ultra-thin films. By engineering the hyperbolicity of these structures, at the activation frequency of diamond nitrogen vacancy centers, we demonstrated a considerable increase of the light emission of this integrated single-photon sources at room temperature.
Finally, in order to enable the fabrication of the originally proposed PHMs components, we readapted the standard glazing angle deposition to a novel approach named "shadowed deposition" **(see Fig.3)**. This technique makes use of a nano-metric mask to create a shadowed region where the deposited films show a longitudinal gradient in the material thickness. This strategy well approximates the originally proposed PHM layout eliminating all the fundamental issues encountered by using the standard GLAD technique (e. g. disuniformity, isles formation at the edge of the curved area, and grow of nano-filament agglomeration with multiple angled deposition). These structures fabricated by using this novel and original methodology (see SEM picture in the inset of Fig.3) represent first prototypes of the planar Hyperlenses and light concentrators proposed in the ATOMIC project and they have been proved to be effective for the modal conversion from high-k modes into low-k modes. This is the key feature to unlock the potentials of hyperbolic metamaterials, which are normally plagued by remarkable propagation loss and poor coupling efficiency.
The scientific throughput of ATOMIC, is expected to strongly influence many fundamental aspects of photonics in the years to come. The materials developed inside ATOMIC enable a new class of ultra-fast and tunable nanophotonic devices for telecom applications and quantum optics. They also pave the way towards future disruptive technologies such as heat assisted magnetic recording and thermophotovoltaics which bring the promise to drastically enhance modern data storage and energy harvesting capabilities. All these results will certainly give a tremendous contribution to the key technologies that will shape our future. Up to date, ATOMIC-related publications account for over 250 citations accumulated over a time span of less than 3 years (source Google Scholar).
(Visit: http://www.asn-lab.org/marie-sk322odowska-curie-actions.html)

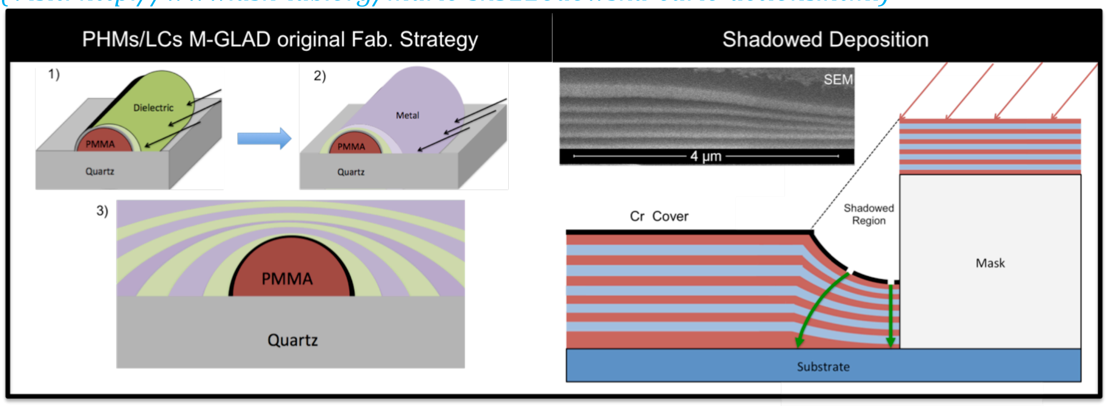

Figure 3- Shadowed deposition Vs standard glazing angle deposition (GLAD).