Ion implantation and irradiation as a tool to engineer 2D transition metal carbides (MXenes)

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Ion implantation is among the most versatile approaches to modify, in a controlled way and with possible access to out-of-equilibrium states, the structure and physical properties of solids. This technique is widely used in the semiconductor industry for doping or for engineering electronic devices. More recently, it has been extended to 2D materials, such as graphene, MoS_2 or WSe_2 [1]. Among these materials, MXenes is an expanding family of layered transition metal carbides and nitrides, with very promising properties for a large number of applications, including energy storage, transparent electronics, sensors, or electromagnetic interference shielding [2].
In this work, and focusing first on the benchmark $Ti_3C_2T_x$ MXene (T_x=F, Cl, or O(H) and x≈2) elaborated as ~100 nm thick spin-coated films (Fig. 1), we show that ion implantation/irradiation offers high flexibility for the design of MXenes, allowing to shape their properties on demand which is a unique asset for applications. By investigating a wide damage range, and using XRD and Electron Energy Loss Spectroscopy in a Transmission Electron Microscope to investigate structural changes and damage together with electronic structure modifications, we demonstrate that ion irradiation can be used to tune the MXene architecture at different levels: modification of the interlayer spacing, tuning of the functionalization groups and control of the structural defects in the MXene sheets. Further, we show that ion implantation can be used to incorporate foreign species (Mn) in $Ti_3C_2T_x$ sheets up to several percent [3]. Moreover, focusing on the V_2CT_z MXene, and using a bottom up approach, we show that the defects introduced by irradiation of its MAX phase precursor V_2AlC, facilitate the chemical etching and drastically reduce the etching time to synthesize macroscopic nanolayered V_2CT_x MXenes [4].

References

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Figure

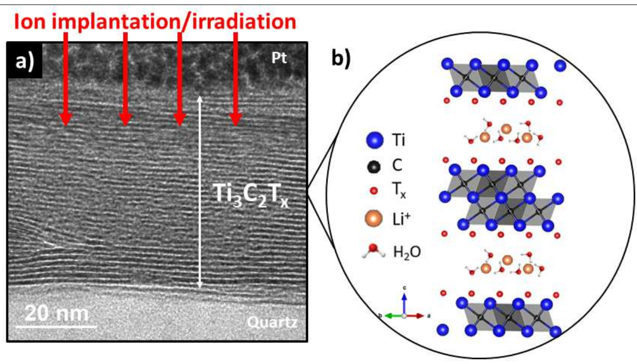

Figure 1: (a) HR-TEM micrograph of a $Ti_3C_2T_x$ thin film (b) Schematic representation of a multilayer stack.