This PhD thesis focuses on the electronic and optoelectronic characterization of devices based on low-dimensional materials and on a first approach to fabrication of 2D transition metal dichalcogenide (TMD) field effect transistors (FETs) and heterostructures. The aim of this research is to investigate the properties of several low-dimensional materials and how they can be affected by light, electron irradiation, and electric field. These effects can be also exploited for some applications, from simple photodetection to a new generation of transistors based on tuneable field emission current.

This work is structured into three chapters. In the first chapter, the fundamentals of devices, like FETs and Schottky diodes, are presented together with the state-of-the-art of some of the most studied low-dimensional materials, i.e. TMDs, graphene, and carbon nanotubes.

The other two chapters are focused on the results obtained during my three PhD years.

In particular, the second chapter is about TMD FETs. Molybdenum disulphide (MoS_2) is one of the most studied TMDs in literature. Nevertheless, the study of MoS_2 FET electron beam influence was something unreported. During the characterization of the materials, the scanning electron microscope (SEM) is a powerful tool to check the material flakes' morphology and to have full control in contacting the device. For this reason, a study about the role of electron beam irradiation is of great interest, especially if it causes dramatic changes in the material's conductivity[1] (***ACS Appl. Mater. Interfaces 2020, 12, 36, 40532–40540***).

On a similar device, field emission properties have been investigated. Using the Fowler-Nordheim theory, MoS_2 flakes show a low turn-on field which can be modulated by applying different voltages at the gate oxide under them. This behaviour can be exploited for the realization of new generation transistors based on field emission phenomenon[2] (***Adv. Electron. Mater. 2021, 7, 2000838***).

In the second chapter, another TMD FET has been studied: Platinum diselenide FET. Among all the results, surely the coexistence of positive and negative photoconductivity is something unusual and of a great interest. Incident light increases its conductivity when it is in high vacuum (positive photoconductivity), while, in ambient pressure, the n-doping induced by the desorption of surface adsorbates prevails and decreases conductivity (negative photoconductivity)[3](***Adv. Funct. Mater. 2021, 31, 2105722***).

In the third Chapter, the focus shifts to carbon-based Schottky diodes and TMD heterostructures for photodetection. The fabrication of graphene-silicon Schottky diodes often involves the formation of a parallel metal-insulator-semiconductor (MIS) structure. This MIS structure affects the reverse current of the device, inducing a deviation (kink) from the standard current-voltage characteristic, because of a tunneling phenomenon occurring through the insulator[4] (***ACS Appl. Mater. Interfaces 2021, 13, 40, 47895–47903***). To exploit this structure behaviour, a platinum-titanium/Silicon junction has been fabricated in parallel to a MIS structure formed by carbon nanotubes (CNTs), silicon nitride (Si_3N_4) and bulk n-type Silicon. This device shows the same kink in the reverse current. However, when irradiated by light either on the MIS or the diode, the device shows a different photocurrent, also depending on the applied voltage bias. This behaviour can lead to different applications, from a voltage bias tuneable photodetector to a logic Boolean device with the position of the light and the applied bias as input variables[5] (***Adv. Electron. Mater.*** **2022, 2200919**).

Finally, in the last part of the third chapter, some examples of FET and heterostructures fabrication are reported. During the PhD course, I spent 6 months (Oct2021-Apr2022) in Aachen, Germany, at the RWTH University, under the supervision of Prof. Max Lemme. During those months, I have learnt how to fabricate standard 2D field effect transistors and 2D TMD heterostructures. For instance, I show, in the last part of this work, some tungsten diselenide (WSe_2) FETs with an on/off ratio up to 10^5 and some MoS_2/WSe_2 heterostructures with a responsivity of about $1\mu A/W$.