Summary

This dissertation deals with new insight in biomedical measurements and applications. In particular, thin films technologies are employed for the developments of sensors and sterile biomedical tools. At this scope, a metrological approach is required for the study and evaluation of three topics for biomedical applications. First of all, the main topic faces the realization of sensors for breath analysis based on niobium oxide thin film obtained via plasma deposition. Then, the second topic deals with the deposition of silicon oxide thin film enriched with copper nanoparticles in order to obtain sterile tools with high barrier properties. Eventually, the last topic regards the effect of a controlled CO_2 atmosphere on the corrosion of a magnesium (Mg) alloy formed by yttrium and neodymium (WE43 alloy). Actually, the corrosion characterization of Mg alloys, for biomedical applications, requires a trustable methodology able to simulate in the best way a biological environment. The latter has been carried out during the research period at Monash University in the frame of Erasmus+/Partner Countries 2018/2019.

Starting from the main topic, it is focused on the development and characterization of sensors for breath test analysis, especially for the detection of acetone, ethanol and hydrogen. Nowadays, breath test measurements are gaining more importance since they allow to obtain fast responses avoiding invasive procedures. In fact, it is possible to diagnose several different diseases by detecting specific biomarkers from the human breath aerosol. Among the different gas sensor technologies, conductometric gas sensors are an interesting low-cost solution because of their small dimensions, which allow to implement them into portable measurement system devices. In this dissertation, conductometric gas sensors formed by a small alumina substrate (about 6 mm x 3 mm) are developed by depositing a small niobium oxide (NB_2O_5) thin film on it as sensing material. From a complete sensing characterization, noteworthy results in terms of sensitivity and selectivity have been obtained toward the detection of acetone and ethanol. The sensitivity, observed by proposed sensors, allows to detect a linear response toward acetone in the concentration range from 1 ppm to 3 ppm making them suitable for breath analyser for diabetes diagnosis. In fact, it is well-known that diabetes can be correlate with acetone concentrations higher than 2 ppm inside the exhaled human breath. Furthermore, high selectivity is achieved; in fact, the sensors show responses only towards acetone and ethanol. The latter is not involved in metabolic human processes avoiding possible interference during the breath test, which could lead to false positive diagnosis. Furthermore, such niobium oxide thin film has been characterized toward ethanol sensing as well. The results exhibit quite good responses making such sensors suitable for ethanol analyser.

Moreover, sensors obtained by depositing NB_2O_5 enriched with platinum (Pt) nanoparticles have been developed in order to modulate the selectivity toward hydrogen detection. In fact, the Pt

enrichment turns out in excellent responses toward H_2 at high concentrations, up to 80000 ppm. In addition, the selectivity shows interesting results since such sensors do not exhibit any responses toward others interferent gases.

The second topic is a proof of concept about the possibility to combine electrochemical impedance spectroscopy and inductively coupled plasma – atomic emission spectroscopy measurements for the evaluation of both corrosion protection effect and antifungal effect of SiO_x thin films enriched with copper nanoparticles obtained by plasma deposition. In fact, fungi and bacteria infections are still an important concern in the hospital environments, which could lead to clinical complications. Nevertheless, Cu has an interesting antifungal effect, and it can be employed for the realization of engineered thin films enriched with Cu nanoparticles, which can be gradually released by a tailored degradation of the film itself. The thin films have been obtained by plasma enhanced chemical vapour deposition for obtaining SiO_x thin films and, at the same time, by a magnetron sputtering in order to embedded Cu particles inside the SiO_x matrix. The analyses were carried out employing simulated body fluids as electrolyte and collecting 5 cc of solution every day in order to monitor the Cu release and comparing it with the results of EIS measurements. The preliminary results are promising and shows a specific correlation between the two techniques.

The third and last topic deals with the effect of CO_2 atmosphere on corrosion of a WE43 magnesium alloy in two different minimum essential medium electrolytes. Nowadays several studies face the possibility to tailor the corrosion of magnesium alloys in order to obtain a controlled bioreassorbtion of implants (e.g. stents). At this scope, a wide number of magnesium alloys have been characterized in simulated body fluids in order to simulate a biological environment. Unfortunately, there is not a common agreement or specific guideline about the methodology to carry out the experimental set up, which can turn out to non-confrontable results. One of the aspect that is commonly ignored is the effect of CO_2 on the corrosion mechanism of magnesium alloys. In fact, CO_2, has an important role as buffering inside the human body, maintaining the pH at about 7.3. At this scope, the comparison between a controlled CO_2 atmosphere and an open-air environment on the corrosion of a WE43 alloy has been carried out, performing both long term and short-term measurements. The results highlight an important difference between the two cases since the corrosion mechanisms are affected both by the buffering effect and by the inhibition of the cathodic particles by the carbonates generated by the CO_2 controlled atmosphere.

To conclude, the interesting results, reported in this dissertation, highlight the importance of appropriate measurement techniques for the characterization of devices and materials for biomedical applications.