Owing to a unique profile of properties such as high specific strength and excellent corrosion resistance, titanium alloys are more and more used for various medical, chemical and especially aerospace applications. β-stabilised Ti alloys have attracted a large attention since this particular class of alloys exhibits the widest panel of performances. However, these alloys show a plasticity driven by dislocation glide so that they generally suffer from a lack of work hardening, which is most of the time a major drawback.

The present thesis aimed at assessing how the triggering of a combination of different plasticity mechanisms by a fine tuning of the chemical composition can enhance the work hardening rate of β titanium alloys. The present work shows that such designed alloys exhibit work hardening rates never reached before, as a result of the synergetic activation of α" stress-induced martensitic (SIM) phase as well as from mechanical twinning.

Each mechanism has been thoroughly characterised in order to estimate its contribution to the overall work hardening rate. Specific characterisation techniques such as synchrotron-based X-ray diffraction, HR-TEM and HR-EBSD used during in situ tensile loading of a Ti-12 wt.% Mo alloy, brought the monitoring of the deformation mechanisms from the nano to the mesoscopic scale. Furthermore, incremental oligo-cyclic shear tests brought some insight in the influence of strain path changes on the mechanical response of the material.