From surface to sub-surface contributions to friction at the nanoscale

The friction phenomenon is a complex manifestation of the nature originated in energy dissipation events owing to the lost work of non-conservative forces. In spite of different surface mechanisms describing the friction phenomenon at the nanoscale, the involved energy in such surface events is not enough to explain friction forces in wearless regime. Indeed, phononic, electronic and magnetic effects are not capable of providing a sufficient energy to explain friction forces. Thus, new contributions are mandatory to reach a satisfactory energy balance among friction mechanisms and lost work by non-conservative friction forces. The aim of the work is to establish sub-surface contributions to friction at the nanoscale. In this study, we report the friction forces at the nanoscale on iron nitride and oxide by nanoindentation followed of unidirectional sliding (NUS) and friction force microscopy (FFM). Two different experimental setups are reported. Moreover, the sub-surface elastic deformation due to indentation was modeled following the classical contact theory from Hertz by using the ABAQUS software. Firstly, the elastic deformation leads to reach elastic energies in the order of lost work of friction forces. Secondly, the sub-surface contributions seem to be more important than the surface contributions to friction at the nanoscale. We discuss these surface and sub-surface mechanisms by dissipation effects associated with surface phonon coupling and sub-surface energy-releasing due to elastic energy dissipation.