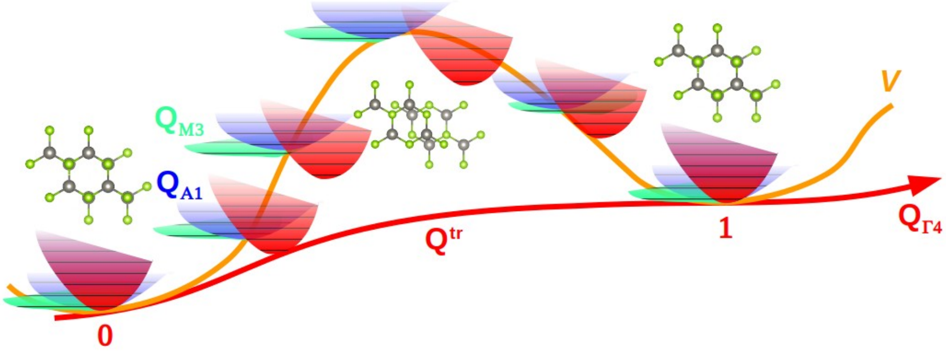
Towards a universal framework to describe and control atom-scale friction

Antonio Cammarata
Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Control Engineering
Karlovo náměstí 13, 121 35, Prague 2, Czech Republic; email: cammaant@fel.cvut.cz

Macroscopic friction is the result of the interplay of several processes occurring at different scales. At the moment, there is no theory which tells us what is the friction coefficient given the atomic description of two surfaces in contact. The control of friction and the design of new tribological materials with target friction response can then be hardly obtained by using purely experimental models. An atomic scale definition of friction is therefore mandatory to provide a deep and, possibly, complete understanding and control of the undelying phenomena.

The aim of this seminary is to show a possible route on how to extract information on the frictional and dissipative response of a system from the only knowledge of its static properties at the atomic level. In parallel, we will outline a possible quantum mechanical system-independent framework which is applicable to any kind of chemistry and atomic topology. To achieve this, the friction response is recast in terms of suitable phonon modes and related scattering tensor elements. This approach allows to control the frictional properties of existing materials in a subtle way; at the same time, the approach suggests how to design new tribological materials with target frictional response. The result of this method is a phonon-based friction theory, where the phonon theory and the quantum mechanics have been used to pave the way towards a universal framework to describe and control friction occurring at the atomic scale. This approach may then pave the way towards a phonon friction theory which can tackle one of the biggest challenges of nanotribology: the calculation of the friction coefficient of two interacting surfaces based on the sole knowledge of the atom types and their geometric arrangement.



References

- [1] A. Cammarata et al. "Tailoring Nanoscale Friction in MX_2 Transition Metal Dichalcogenides", Inorganic Chemistry **54**, 5739 (2015)
- [2] A. Cammarata, "Phonon–phonon Scattering Selection Rules And Control: An Application To Nanofriction And Thermal Transport" RSC Advances **9**, 37491 (2019)
- [3] A. Cammarata et al. "Overcoming Nanoscale Friction Barriers In Transition Metal Dichalcogenides", Physical Review B **96**, 085406 (2017)
- [4] A. Cammarata et al. "Atomic-scale Design Of Friction And Energy Dissipation", Physical Review B **99**, 094309 (2019)
- [5] A. Cammarata et al. "Control Of Energy Dissipation In Sliding Low-Dimensional Materials", Physical Review B **102**, 085409 (2020)
- [6] B. Perotti, A. Cammarata et al. "Phototribology: Control of Friction by Light", ACS Appl. Mater. Interfaces **13**, 43746 (2021)
- [7] A. Cammarata et al. "Fine control of lattice thermal conductivity in low-dimensional materials", Physical Review B **103**, 035406 (2021).
- [8] A. Cammarata et al. "Effect of Noninteracting Intercalants on Layer Exfoliation in Transition-Metal Dichalcogenides", Physical Review Applied **15**, 064041 (2021)
- [9] A. Cammarata et al. "Current perspective towards a general framework to describe and harness friction at the nanoscale", Progress in Surface Science **99**, 100753 (2024)