**Adhesion and friction in 1D and 2D systems**

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In this presentation, I will focus on aspects of adhesion and friction that I have encountered in two low dimensional systems, namely carbon peapods and graphene.

Adhesion and friction between a 2D system and the substrate it is deposited on are key parameters governing the transfer of deformation from the substrate to the 2D system, and understanding the mechanism and limits of such strain transfer is a most needed step towards the development of strain engineering at the nanoscale. This includes applications in straintronics, NEMS devices, or new nano-composites. Here, we have studied the limits of biaxial compressive strain transfer between SiO2, diamond and sapphire substrates and graphene. Using high pressure – which allows maximizing the adhesion between graphene and the substrate on which it is deposited – we show that the relevant parameter governing the graphene mechanical response is not the applied pressure but rather the strain that is transmitted from the substrate. Under these experimental conditions, we also show the existence of a critical stress beyond which strain transfer is partial. The obtained results are important as they fix the limits of validity of the total strain transfer between the substrate and the graphene layer; they invite to cast a new look at mechanical strain experiments on deposited graphene as well as to other 2D layered materials.[[1]](#footnote-1)

Understanding friction at the atomic scale passes through the understanding of friction in its simplest form, *i.e.* in one dimension. Analytical models for friction in 1D are often based on the Frenkel-Kontorova representation of two interacting sub-lattices[[2]](#footnote-2), but despite their “old age” these models are difficult to verify experimentally by lack of the appropriate system: predicted in the 80’s, the Aubry transition2,[[3]](#footnote-3) (also known as transition by breaking of analycity) was only witnessed recently in 1D trapped cold atoms systems[[4]](#footnote-4).

Peapods (C60 fullerenes adsorbed inside single walled carbon nanotubes) constitute a model 1D system, stable on a wide (1100 K) temperature range – which is rare in the 1D world. In this system, the joined study of the structure and dynamics allowed studying experimentally some predicted – yet never observed – phenomena in 1D systems.[[5]](#footnote-5),[[6]](#footnote-6) Using inelastic neutron scattering, diffraction and analytical models, we have shown that the subsystem that is the fullerene chains can, at higher temperatures, be fully described *without* accounting for the hosting nanotube. This means that for these temperatures, there is *no friction* in the peapod system. Recent results on both monomer and polymerized peapods (in which individual rotations are blocked) show the emergence of a friction at low temperature, the order parameter having a seemingly similar behavior as what is expected in an Aubry transition2,3 with a critical temperature of 230 K. The role one the nanotube’s phonons in this transition will be discussed.

1. Bousige *et al.*, Nano Letters (in revision) [↑](#footnote-ref-1)
2. Peyrard and Aubry, J. Phys. C: Solid State Phys. **16** (1983), 1593 ; Janssen *et al.* Eur. Phys. J. B **29** (2002), 85 [↑](#footnote-ref-2)
3. Manini *et al.*, J. Phys.: Cond. Mat. **28** (2016), 293001 [↑](#footnote-ref-3)
4. Bylinskii *et al*. Nature Mater. **15** (2016), 717 [↑](#footnote-ref-4)
5. Bousige *et al.*, Phys. Rev. B **86** (2012), 045446 [↑](#footnote-ref-5)
6. Bousige *et al.*, Phys. Rev. B **87** (2013), 195438 [↑](#footnote-ref-6)