# A Tuning-fork low-temperature nanotribometer

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Quartz Tuning Fork (TF) has been in recent years successfully implemented in force detection schemes for scanning probe microscopy applications [1, 2]. Here we report its use as a nanotribometer for exploring shear and friction force in atomic size areas. The idea behind such a non contact shear and friction forces detector, is to take advantage of the mechanical resonance of a TF which has a large q-factor ($q_{air}$~6000, $q_{vac}$~40000 at room temperature) which is a function of the tip-sample dissipative forces.

We describe two models to understand the behaviour of the TF and its calibration. First, a mechanical model (fig 1, left) similar to mechanical pendulum or spring base [3]. Second, an electrical model or the Butterworth-Van Dyke circuit (fig 1, right) [4].

We used a phase locked loop (PLL) from NanoMagnetics Instruments Ltd. to measure the q-factor and the resonance frequency for various TFs. We measure the reactive forces that are associated with the combined local elastic properties of the sample and the tip, and calculated the damping rate associated with changes of the tip-sample distance.

Finally, we show some of the results using the TF-nanotribometer in Au and Pb, measuring at different temperatures from 4.2 K to room temperature in high vacuum.

## References:

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[2] Khaled Karrai and Ingo Tiemann. Phys. Rev. B, **62** (2000) 13174-13181.
[3] J.M. Friedt and É. Carry. Am. J. Phys. **75** (2007) 415-422.
[4] J. Rychen, T. Ihn, P. Studerus, A. Herrmann, K. Ensslin, H. Hug, P. J. A. van Schendel, and H. J. Güntherodt. Rev. Sci. Instr. **71** (2000) 1695-1697.

**Figures:**

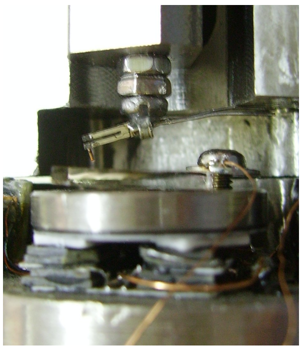

**Fig 1.** Tuning-fork low-temperature nanotribometer.

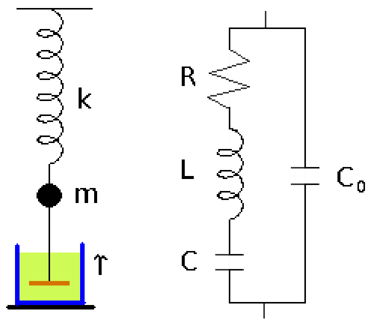


**Fig 2.** (Left) Mechanical model, m is effective mass of the fork's arms, k is static spring constant and g is the damping rate term. (Right) Electrical model. Butterworth-Van Dyke circuit.