NANOTRIBOLOGY OF PEARLS – INFLUENCE OF THE ORGANICS' CONTENT ON THE FRICTIONAL DISSIPATION OF SHEET NACRE

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ABSTRACT

Sheet nacre is a hybrid biocomposite with a multiscale structure, including nanograins of $CaCO_3$ and two organic matrices [1] : (i) the *interlamellar,* mainly composed of β-chitin and proteins, and (ii) the *intracrystalline* composed by silk-fribroin like proteins. This material is currently studied for the manufacture of small prostheses – *eg.* rachis or dorsal vertebra prostheses [2] – which can be subjected to *slip* or fretting motion at the nanoscale. In a recent work, it has been demonstrated that the tribological behavior of sheet nacre is completely controlled by the organic matrices on a large range of frictional dissipated powers. Besides, various dissipative mechanisms are involved within the contact as function of the injected power. Thus, an interesting lubricant effect [3] due to the presence of an organic tribolayer generated by the organic *interlamellar* phase can be observed in association with some very long recovery-time viscoelastic deformations of the organomineral tablets [1, 3]. However, the influence of these organic matrices on the frictional behavior is not completely understood yet.

In order to address this issue, the role of the organic phases in the dissipation process will be investigated in the present work by controlling the organics' content within the nacre specimen. This content is varied by using pearls created by freshwater bivalve mollusks *Hyriopsis cumingii* displaying a polymorph sheet nacre in the same pearl sample – *ie, lustrous* aragonite area *vs*. *milky* vaterite area with a lack of *lustrous*. Besides a different crystallographic structure (hexagonal *vs.* quadratic) the *milky* vaterite area own at least 20% more organics with respect to the *lustrous* aragonite area [4, 5].

In this work, evolution of friction laws of the *lustrous* and *milky* pearls are both studied as a function of sliding amplitude and velocity by using a AT-cut quartz crystal resonator (QCR, 10 MHz) which is in contact with the both pearl area at constant normal load (8 mN). The surface displacement amplitudes of the AT-cut QCR – *ie,* the sliding amplitude – is controlled by means of a Vector Network Analyzer (VNA *R&S ZNC 3*) [6-8]. In order to study the interaction between the QCR and pearl's asperities, experiments were performed over a wide amplitude range – from 0 to 40 nm – by changing the drive level provided by the network analyzer [7]. Thus, induced sliding velocity lies from $mm.s^{-1}$ to $m.s^{-1}$ which corresponds to an injected mechanical power from nW to mW.

When the pearl is applied at constant normal load on the QCR, the network analyzer sweeps the frequency across the resonance and measures the resonator's electrical admittance [8]. At the resonance frequency, the real part of the latter forms the well-known resonance curve which is characterized by its quality factor *Q*. Hence, any variations of resonance frequency (*dF)* and dissipation factor ($dD = dQ^{-1}$) can be studied over time as function of the sliding amplitude or sliding velocity [9].

As a result, friction laws, static and dynamic contact parameters can be extracted using parametric identification of *emerging* frictional behavior on various scales [10, 11]. Thus, the frictional behavior can be accurately studied – for strong bonding conditions – by fitting the evolution of *slip-time (ie. dD/dF) vs.* amplitude by power-laws [10]. Hence, the power-law exponent continuously changes *vs.* amplitude. Since this evolution is equivalent to those of friction force *vs.* velocity [10], friction laws can be accurately extracted for the both *lustrous* and *milky* area and then, studied as function of the organics' content and the injected power within the contact.

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