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Comment on "Origin of Friction Anisotropy on a Quasicrystal Surface"

K. McLaughlin
University of South Florida

D. Rabson
University of South Florida

Patricia A. Thiel
Iowa State University, thiel@ameslab.gov

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Abstract
A Comment on the Letter by Aleksander E. Filippov, Andrea Vanossi, and Michael Urbakh, Phys. Rev. Lett. 104 074302 (2010). The authors of the Letter offer a Reply.

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Filippov, Vanossi, and Urbakh [1] suggest that the giant frictional anisotropy observed with atomic-force microscopy (AFM) on the twofold surface of a decagonal quasicrystal [2] could be due, in part, to differing length scales in the quasiperiodic x and periodic y directions rather than to quasiperiodicity. The numerical calculations they present do not justify the conclusion. Here, we address three main points. First, the parameters in Ref. [1] do not actually test the hypothesis. We compare the authors' results to those of two direct tests. Second, we point out an ambiguity in the authors' interpretation of the scanning-tunneling-microscope (STM) images in the experiment and find that, when the images are correctly understood, the same model gives results contrary to the conclusion of Ref. [1]. Third, we discuss broader experimental reasons to expect dynamics in the sample to dominate dissipation in the AFM cantilever, the mechanism in Ref. [1].

To distinguish effects of length scales and quasiperiodicity, we considered a potential that is periodic in both directions, with y values unchanged but an x periodicity set to the mean of the Letter's quasiperiodic spacings, preserving the peak shapes and scales. The resulting friction is 63% larger in the y than in the (formerly aperiodic) x direction. While considerably smaller than the anisotropies in Ref. [1] and the experiment, this result is compatible qualitatively with the conclusion that quasiperiodicity may be less important than length scale. This conclusion is further compatible with one-dimensional calculations we have carried out by using a potential that can be tuned continuously from periodic to quasiperiodic [3], where the friction shows no systematic change.

One is left wondering whether the frictional anisotropy in the model of Ref. [1] is influenced more by anisotropy in peak spacings or in peak shapes. To test this, we kept the peak positions as in Ref. [1] but set the two peak widths equal (0.16 nm). The result was a $\approx 29\%$ frictional anisotropy *in the reversed sense*: the quasiperiodic direction showed greater friction. The authors' result, therefore, rests on anisotropy in peak width more than on peak spacing. However, we find no compelling justification for their choice of peak widths.

The widths and spacings of Ref. [1] appear to be inferred from only the most prominent features of STM images. However, apparent heights in these images are strongly influenced by electronic effects [4] and do not correspond to topography felt by an AFM tip. Experimental STM images combined with a bulk structural refinement show nearly equivalent atomic rows closer by a factor of τ^2 than those selected by the authors, where $\tau = (1 + \sqrt{5})/2$. When we rerun the model with all x-direction lengths shortened by τ^2, we find that the peak friction occurs not in the periodic direction but at an angle of roughly 40°, contrary to Fig. 2(a) of Ref. [1].

In short, the anisotropy and its origin are quite sensitive to the parameters chosen. However, experimental frictional anisotropy, for this surface, is robust. It is observed with AFM under widely different conditions [2,5]. It is also observed with a *much larger* (20 μm contact diameter) pin-on-disk apparatus after the pin breaks through the native oxide layer [5]. The pin-on-disk experiment does not include an AFM cantilever, so the mechanism must be different. In all cases, friction is lowest in the quasiperiodic direction. In addition, it has long been known that quasicrystals show lower macroscopic surface friction than do periodic phases of similar composition [6]. We suggest that the origin of the friction anisotropy on the twofold decagonal surface remains an open question. Phonons are an obvious candidate but may not suffice; electronic effects may also play a role. As Filippov, Vanossi, and Urbakh note, such effects are missed in their Langevin approach.

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K. McLaughlin and D. Rabson
Department of Physics
University of South Florida
Tampa, Florida, USA

P. Thiel
Iowa State University and Ames Laboratory
Ames, Iowa, USA

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