Characterization of the ILs

The ionic liquids were synthesized in our laboratory with great care and were transparent and colorless liquids. The halide content in [C₄mim][BF₄] was maintained below the solubility limit of AgCl in water (1.4 mgL⁻¹), which was checked by adding AgNO₃ solution. For the [C₄mim][NTf₂], halides in the aqueous phases in contact with the ILs could not be detected by using AgNO₃ solution. The water contents of [C₄mim][BF₄] and [C₄mim][NTf₂] determined by Karl-Fischer titration were 680 and 310 ppm, respectively.

Characterization of silica surfaces

Fig. S1 shows typical FECO image of the silica surface in adhesive contact in air. When the surfaces are brought into contact, the shape of the fringe is transformed from curve to flat due to deformation of the surface. By measuring the length of the flatten line, we can estimate the contact line to be typically tens micrometers. As seen in Fig. S1, the flat lines was well-defined without irregularity. Therefore the silica films were found to be sufficiently smooth and have uniform thickness over a distance of tens micrometer.
On the reliability of parameter of $b_2$ and $k_2$

Fig. S2 Typical fitting results for the resonance curve of [C$_4$ mim][BF$_4$] ($D = 1.9$ nm, $N = 0.39$ mN) with different parameters of $b_2$ and $k_2$.

Fig. S2 shows the resonance curve and the corresponding fitting curves with different parameters. As clearly seen in Fig. S2, both fitting curves agree with the resonance curve. Whereas the fitting results show similar values of $b_2$, the obtained parameter of $k_2$ are greatly different. Hereafter we used the best fitting results of $b_2$ as shown in the insets of Fig. 4.