Supplementary Information

Preparation and property of ZrO_2/GO multi-layered nanocomposite lubricating film

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Surface preparation of substrates and the construction of SAMs

N-Type single-crystal silicon (100) wafers, polished on one side, were used as substrates. The silicon wafers were immersed in Piranha solution (a mixture of 98% H_2SO_4 and 30% H_2O_2 with a volume ratio of 7:3) at 90 °C for 30 min. Then they were thoroughly rinsed with ultrapure water and dried in N_2 flow. This freshly treated silicon wafers were used for the following deposition of APTS-PDA self-assembled monolayers (SAMs).

In order to increase the bonding strength of GO with the silicon substrate and endow such ZrO_2/GO nanocomposite film wide substrate applicability, the pretreated silicon substrates were first modified with APTS and PDA SAMs,

respectively, by subsequently putting into a 5 mM APTS solution in a mixture of acetone and water (the volume ratio of acetone and water was 5:1) for 30 min, and then a dopamine solution in Tris-HCl (pH = 8.5) for 6 h. Between immersions, samples were thoroughly rinsed in ultrapure water and dried completely with N_2 flow.

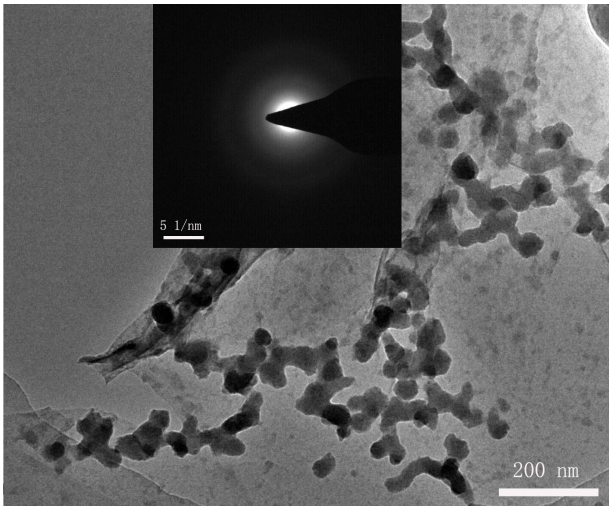

Figure S1. FE-TEM image of simulation reaction in solution of the proposed method for the preparation of ZrO_2/GO composite thin film after being kept at 50 °C for 30 min and the corresponding SAED patterns is shown as inset.

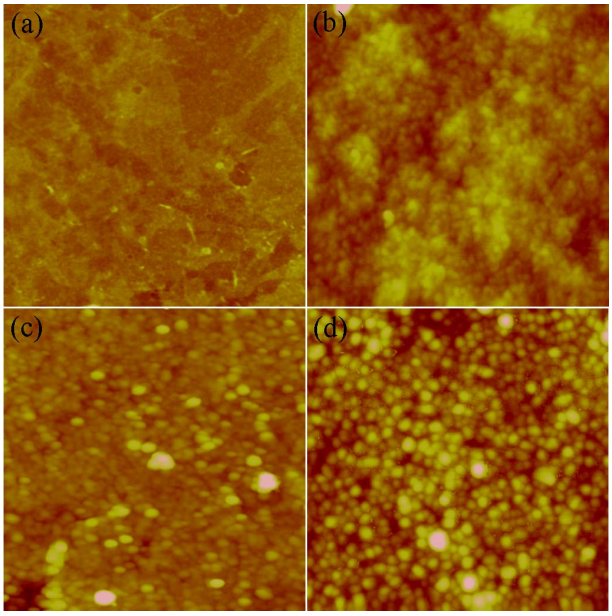

Figure S2. AFM images of the 500 °C annealed ZrO_2/GO nanocomposite film with the scanning area and the data scale of 5×5 μm^2, 50 nm (a) and 1×1 μm^2, 20 nm (b), respectively; AFM images of 900 °C annealed ZrO_2/GO nanocomposite film with the scanning area and the data scale of 5×5 μm^2, 50 nm (c) and 1×1 μm^2, 20 nm (d), respectively.

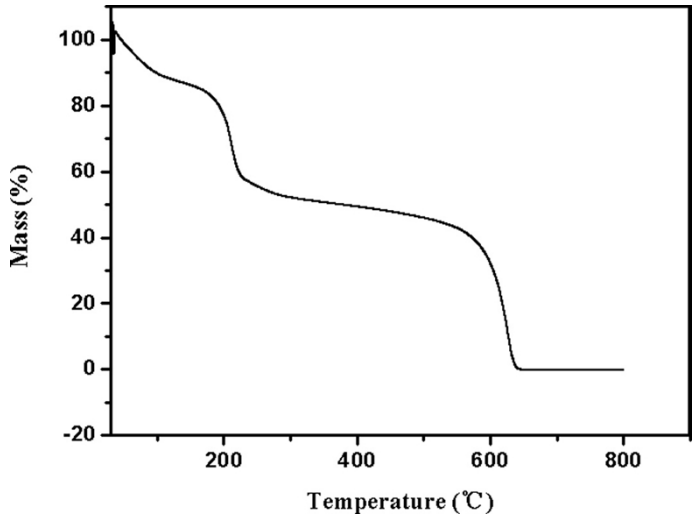

Figure S3. TG curve of GO powder at a heating rate of 10 °C/min in air.

Table S1. Hardness and reduced modulus (Er) of homogenous ZrO_2 thin film at an indentation depth of 30 nm.

Sample	Hardness (GPa)	Er (GPa)
As-deposited	1.49 ± 0.12	19.08 ± 2.76
500 °C annealed	15.88 ± 0.40	186.83 ± 3.63
900 °C annealed	16.63 ± 0.38	168.79 ± 4.6

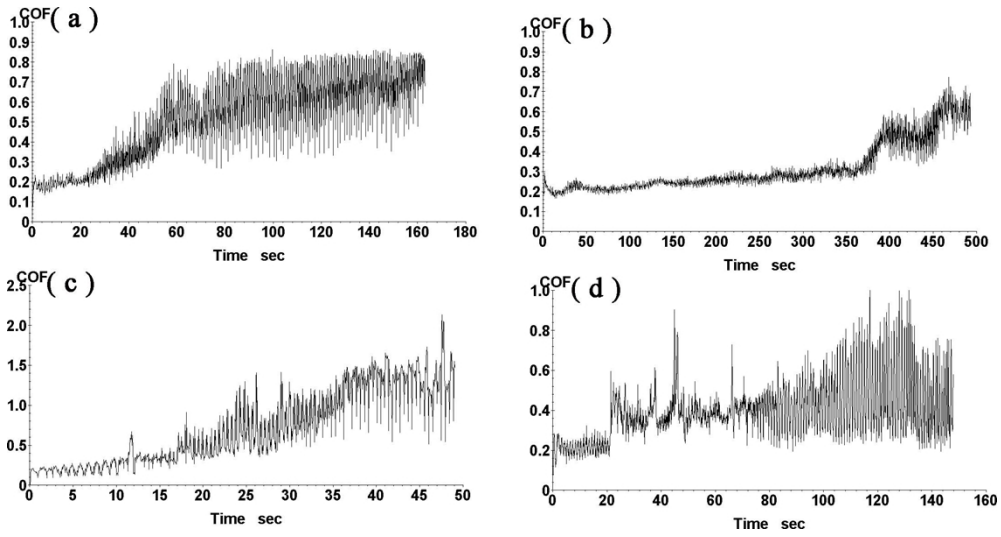

Figure S4. Variation in friction coefficient with time for 500 °C (a, c) and 900 °C (b, d) annealed homogeneous ZrO_2 film under a fixed sliding frequency of 1 Hz and the applied loads of 0.1 N and 0.3 N, respectively.

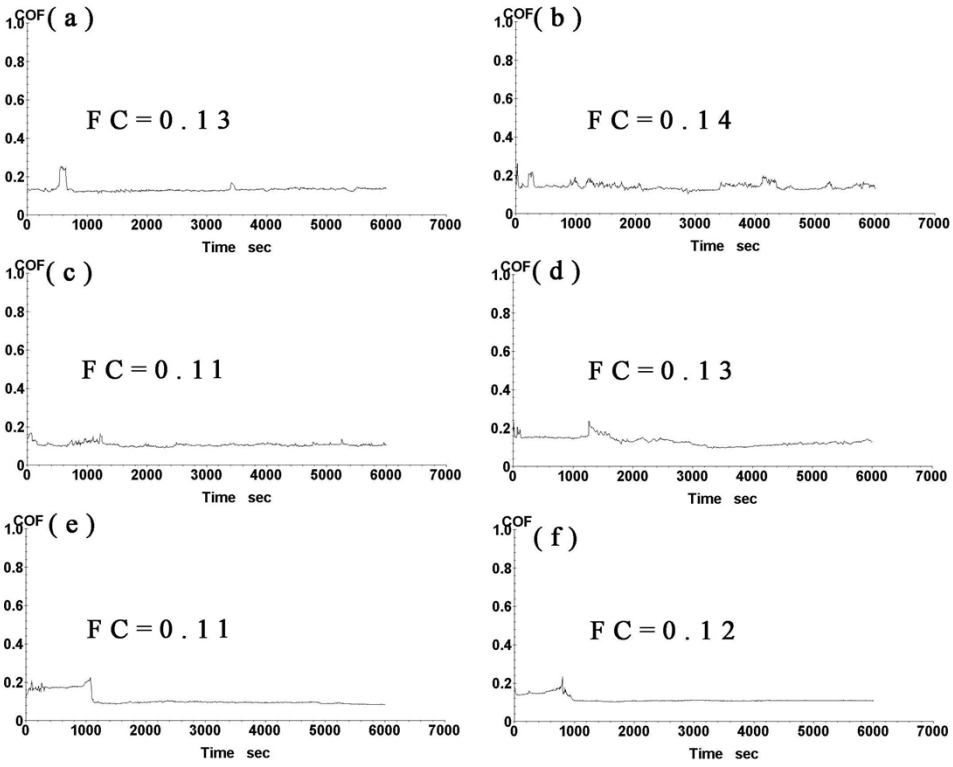

Figure S5. Variation in friction coefficient with time for 500 °C (a, c, e) and 900 °C (b, d, f) annealed ZrO_2/GO multi-layered nanocomposite film under a fixed sliding frequency of 1 Hz and the applied loads of 0.3 N, 0.5 N and 1.0 N, respectively. The average friction coefficient (FC) was given above the corresponding curve.

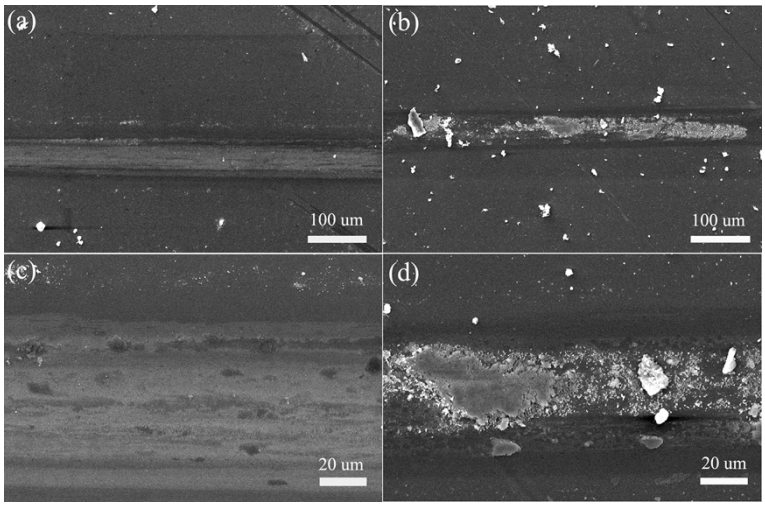

Figure S6 SEM micrographs of the worn surfaces for homogeneous ZrO_2 thin films sliding against steel ball under the applied load of 0.1 N and a fixed sliding frequency of 1 Hz: (a) and (c) 500 ^oC annealed homogeneous ZrO_2 thin film, (c) and (d) 900 ^oC annealed homogeneous ZrO_2 thin film.

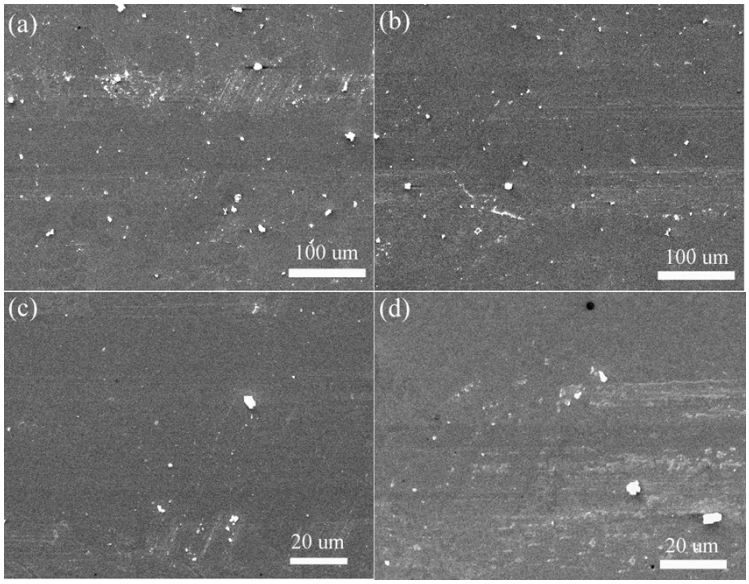

Fig. S7 SEM micrographs of the worn surfaces for ZrO_2/GO nanocomposite films sliding against steel ball under the applied load of 0.5 N and a fixed sliding frequency of 1 Hz: (a) and (c) 500 ^oC annealed ZrO_2/GO nanocomposite film, (b) and (d) 900 ^oC annealed ZrO_2/GO nanocomposite film.