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A simple one-step solution deposition process for constructing high-performance amorphous zirconium oxide thin film

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Supplementary Information

2.2.1. Silicon surface preparation

N-type (100) single-crystal silicon 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 under N_2 flow. These freshly treated wafers were used for the following deposition of self-assembled monolayer (SAM).

2.2.2. Construction of SAM

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In order to increase the bonding strength of PDA with substrate, the pretreated silicon substrates were subsequently put into a 5 mM APTS solution in a mixture solution of acetone and water (the volume ratio of acetone to water was 5:1) and kept for 30 min. Then the wafers were taken out and ultrasonically cleaned in acetone and water, respectively, to remove the physically absorbed deposits, followed by blowing dry with N_2, generating the APTS-SAM modified silicon substrates. Subsequently, the APTS-SAM modified silicon substrates were immersed into the Tris-HCl (pH 8.5) solution of DA and kept for 6 h under stirring, then removed and ultrasonically cleaned in water followed by drying under N_2 blow. For convenience, the obtained sample was coded as Si-APTS-PDA.

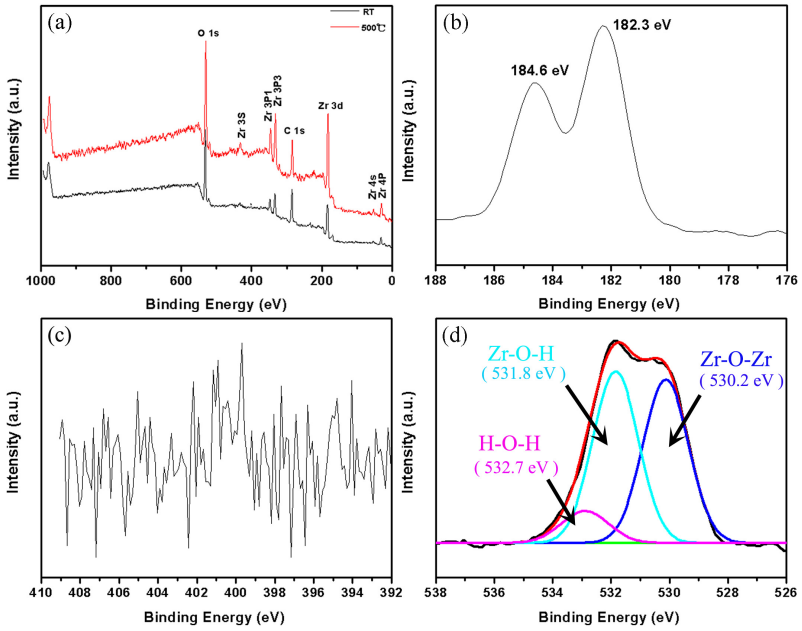

Fig. S1 XPS spectrum of the annealed ZrO_2 nanocomposite film at 500 °C: (a) XPS survey spectrum; (b) XPS spectrum of Zr 3d; (c) XPS spectrum of N 1s; (d) deconvolution result of XPS O 1s core-level spectra.

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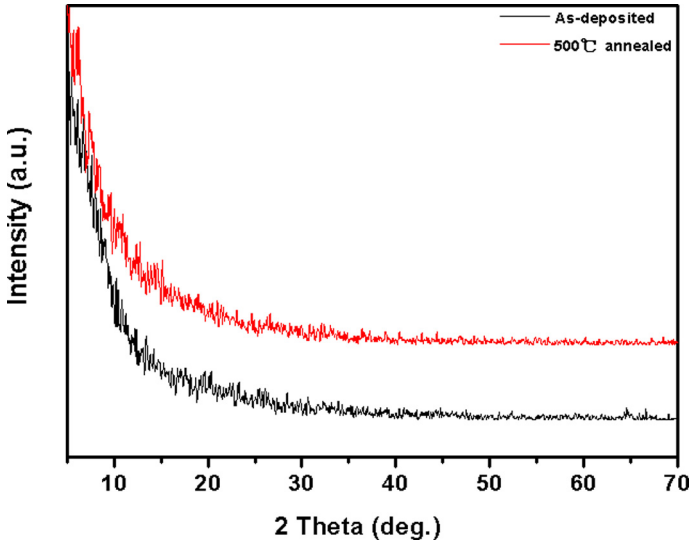

Fig. S2 GIAXRD patterns of the as-prepared ZrO_2 homogenous film and the film annealed at 500 °C for 1h.

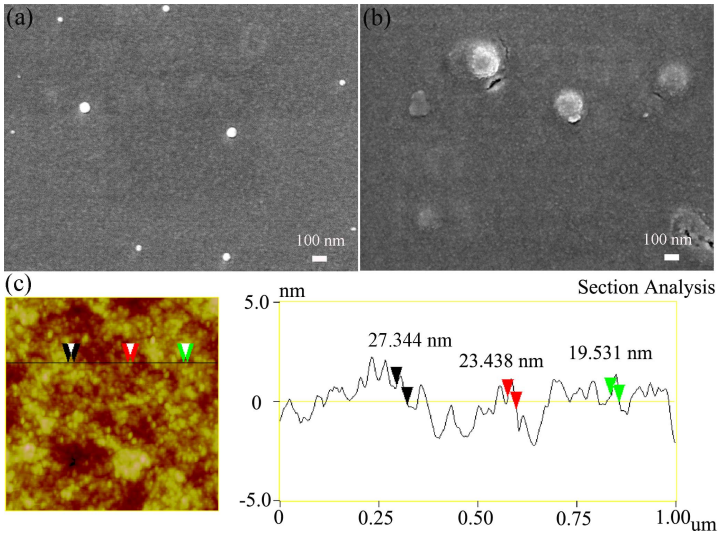

Fig. S3 (a) FE-SEM image of the 500 °C annealed ZrO_2 nanocomposite film; (b) FE-SEM image of 500 °C annealed homogeneous ZrO_2 film; (c) AFM morphology of the 500 °C annealed ZrO_2 nanocomposite film with a scanning area of 1 μm × 1 μm and the corresponding section analysis.

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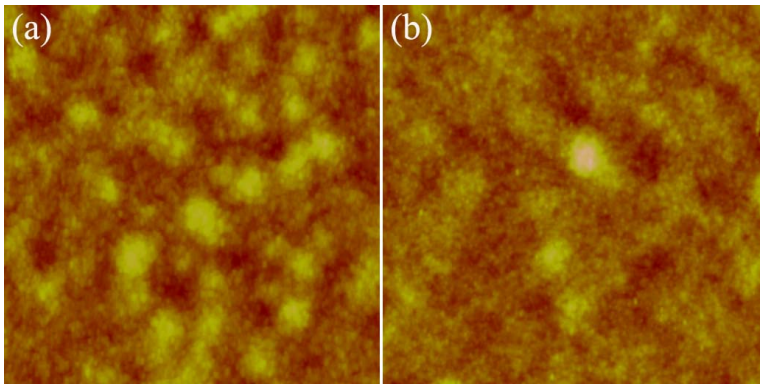

Fig. S4 AFM morphology of (a) the as-deposited and (b) the 500 °C annealed ZrO_2 nanocomposite film with a scanning area of 5 μm × 5 μm and the Z range of 50 nm.

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

Samples	H (GPa)	Er (GPa)
As-deposited	1.416	19.084
500 °C annealed	15.874	186.828

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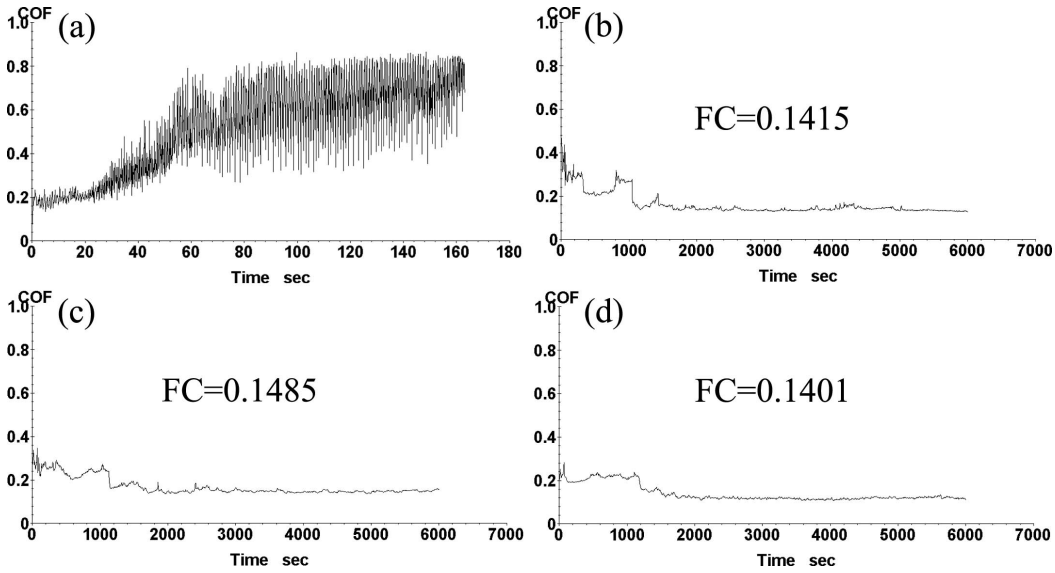

Fig. S5 Variation in friction coefficient (FC) with time for various film samples under different applied loads and a fixed sliding frequency of 1 Hz: the 500 °C annealed homogenous ZrO_2 at the load of 0.1 N (a); the 500 °C annealed ZrO_2 nanocomposite film under the loads of 0.3 N (b), 0.5 N (c), and 1.0 N (d). The stable friction coefficient was given above the corresponding curve.

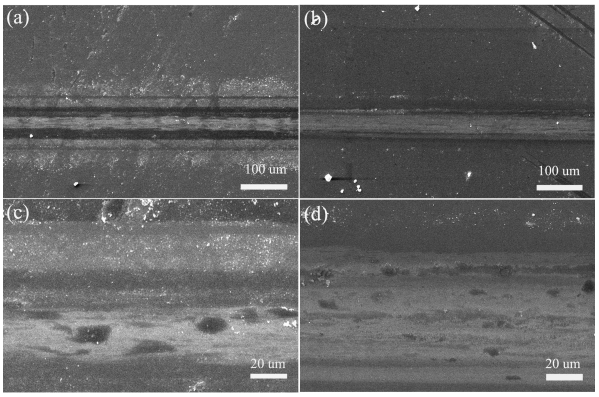

Fig. S6 SEM micrographs of the worn surfaces for homogeneous ZrO_2 thin films sliding against steel ball under the applied load of 0.1N and a fixed sliding frequency of 1 Hz: the as-deposited homogeneous ZrO_2 thin film (a) and (c), and 500 ^oC annealed homogeneous ZrO_2 thin film (c) and (d).