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Electronic Supplementary Information

Observation of Viscoelasticity in Boron Nitride Nanosheet Aerogel

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Content:

Materials

Commercially available BN powders with the size of 2.0 μm were purchased from Denka (Japan). Isopropanol (AR Grade, 99.5%) and sodium cholate was purchased from Aladdin. The deionized water was purified using the Milli-Q system (Millipore, Billerica, MA, USA).

Characterization

Transmission electron microscopy (TEM) micrographs were taken by transmission electron microscopy (G2 F20, FEI Tecnai) with an accelerating voltage of 200 kV. TEM sample was prepared by dropping NF-BNNSs solution on the copper grid, following by drying. SEM micrographsc of BNNS aerogel were obtained using a field-emission scanning electron microscope (Nova NanoSEM 450, FEI) with 10 kV accelerating voltage. The viscoelastic properties were examined by utilizing a dynamic mechanical analyzer (DMA, TA, Q800) in compression mode. The tests were carried out in a chamber with flowing N_2 at a rate of 100 mL/min. The dynamic viscoelasticity was characterized when a sinusoidal stress was applied to the sample and a resultant sinusoidal strain was measured. The measurements were performed at 1 Hz and at a heating rate of 3 °C /min from 30 to 200 °C.

Preparation of NF-BNNSs

NF-BNNSs were prepared via a combination of liquid exfoliation and noncovalent functionalization methods. Approximately 0.5 g of BN powders with the size around 2 μm was dispersed in isopropanol with a concentration of 5 mg mL^{-1}. The dispersion was sonicated in a low power sonic bath for 14 h, resulting in milky white dispersion.

The dispersion was then centrifuged at 1000 rpm for 20 min. After centrifugation, the supernatant was filtered against a membrane (0.22 μm). The filter cake was dispersed in 20 mL 0.05 wt% surfactant sodium cholate (SC) ultrapure water solutions and sonicated for another 2 h. The solution was then filtrated to remove the excess of SC. The filter was dispersed once again in deionized water, obtaining NF-BNNSs solution with 10.0 mg mL^{-1}.

Preparation of BNNS aerogel

In a typical procedure for synthesis of a BNNS aerogel of 21 mg cm^{-3}, NF-BNNSs solution (5.0 mL, 10.0 mg mL^{-1}) was mixed with BDGE (25 mg) in a 5-mL cylindrical glass vial, which was then placed in ambient temperature for 24 h to obtain a BNNS hydrogel. The hydrogel was then immersed in a dry ice bath to be frozen for 24 h. After frozen-drying for 48 h, BNNS aerogel was produced. To enhance the interfacial strength and mechanical properties, the aerogel was thermally cured at 150 °C for four hours. BNNS aerogels with different BDGE contents (10, 20, and 30 wt%, respectively) were prepared by the same process as described, but just by adjusting the concentration of the respective BNNS solution. The prepared BNNS aerogels were designated as, BNNS aerogel-10, BNNS aerogel-20, and BNNS aerogel-30, respectively. The accurate BDGE content of BNNS aerogel-10, BNNS aerogel-20, and BNNS aerogel-30 were calculated by thermogravimetric analysis (TGA), to be approximately 9.1, 17.6, and 29.3 wt%, respectively, as shown in Figure S2.

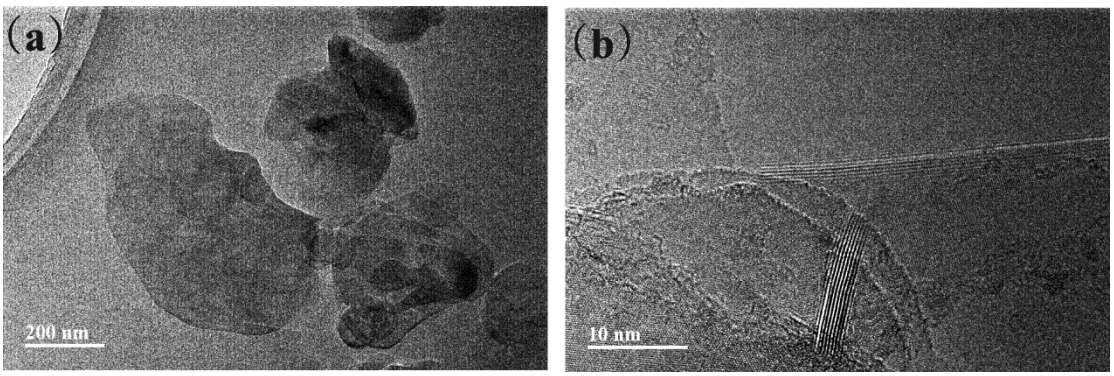

Figure S1. TEM micrographs of the BNNSs at low (a), and high (b) magnifications, respectively.

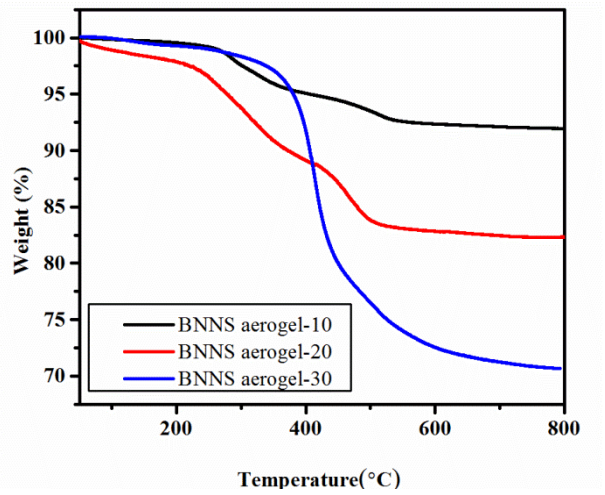

Figure S2. TGA of BNNS aerogels with different BDGE contents.

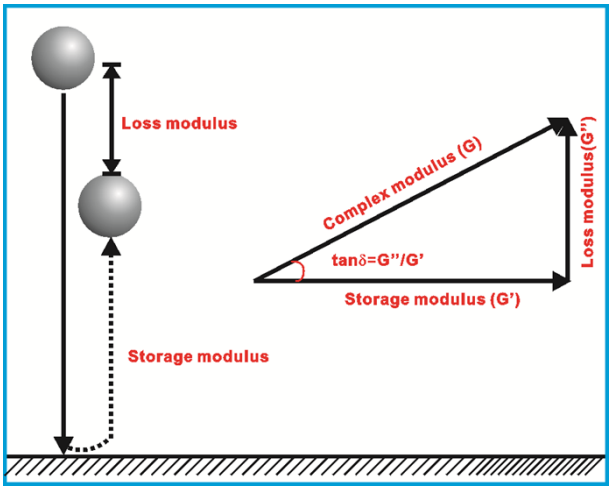

Figure S3. Schematic of viscoelastic property calculation procedure from stress-strain relation.

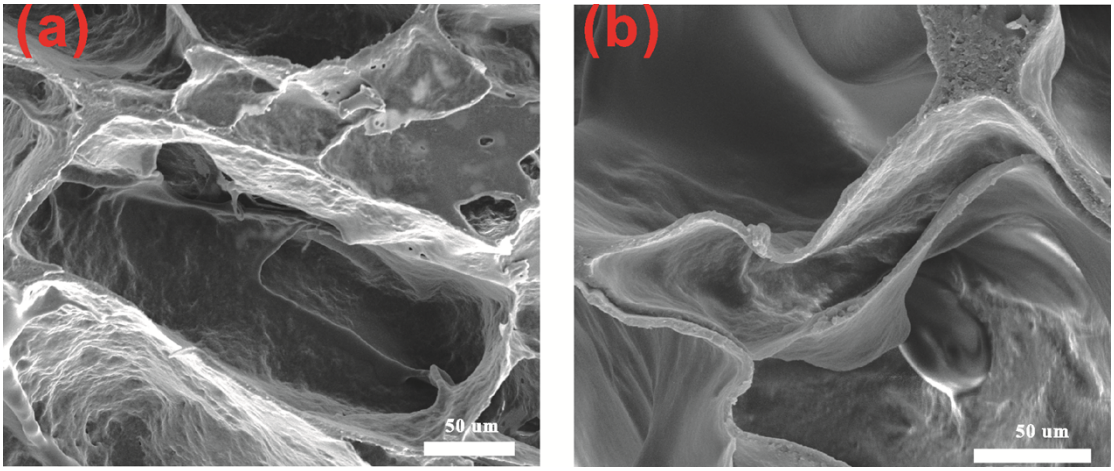

Figure S4. SEM micrographs of celluar structures of BNNS aerogel before (a), and after (b) irreversible compression.

Table S1. The simulation parameters of the generalized Voigt-Kelvin model under different test conditions.

Test condition	τ_1 (min)	τ_2 (min)	τ_3 (min)	τ ($\tau_{1+}\tau_{2+}\tau_3$) (min)
0.005 MPa (30 °C)	0.63	0.7	3.62	4.95
0.01 MPa (30 °C)	0.25	0.92	3.65	4.82
0.02 MPa (30 °C)	0.71	0.20	2.94	3.85
0.01 MPa (60 °C)	0.30	0.32	3.07	3.69
0.01 MPa (90 °C)	0.25	0.03	2.76	3.04
0.01 MPa (180 °C)	0.19	0.19	0.19	0.57

Table S2. The simulation parameters of the Weibull-distribution function under different test conditions.

Test conditions	ε_{υ} (%)	t_0 (min)	$\eta\tau$ (min)	$\beta\tau$	ε_{∞} (%)
0.005 MPa (30 °C)	5.35	10.01	2.85	1.00	0
0.01 MPa (30 °C)	16.82	10.0	5.12	0.65	5.34
0.02 MPa (30 °C)	20.30	10.04	9.50	0.80	44.49
0.01 MPa (60 °C)	49.31	10.02	0.04	1.00	0.98
0.01 MPa (90 °C)	163793.4	9.99	0.007	1.00	0
0.01 MPa (180 °C)	-	-	-	-	-

Note: cannot be simulated.