Supporting Information for

Ultralight three-dimensional boron nitride foam with ultra-low permittivity and superelasticity

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Method details

Fabrication of the BN foam. Nickel foams (Alantum Advanced Technology Materials, Shenyang) were first annealed at 1000°C for 2h under 10 sccm H_2 (50 Pa) to reduce oxide layers of Ni foam and eliminate the carbon contaminate. Then the borazane powder placed in another baking oven was heated to a certain temperature (60°C ～ 130°C) until the pressure increased to around 60 Pa to provide the precursor. After a growth process of 1h, the furnace was cooled to room temperature quickly under the protection of H_2 flow. Before the removal of Ni foam, the sample was dip-coated with a thin layer of PMMA (3 wt% PMMA in anisole). After etched in 3M HCl solution overnight to remove the Ni template, the BN-PMMA was washed by DI water for several times. Finally the PMMA was removed by heating the BN-PMMA at 700°C for 1h in air.

Structure and performance characterizations. The structures of the samples were characterized by SEM (Zeiss EVO 18), TEM (FEI Tecnai G2 20, 200kV), X-ray Energy Dispersive Analysis (Bruker QM100) and Raman spectroscopy (Renishaw Micro-Raman spectrometer, 514.5 nm argon ion laser). No metal coating was deposited on the BN foam surface for the SEM measurements. For TEM observations, BN foam was ultrasonically dispersed in ethanol for 5 min and then dropped onto a TEM grid. Thermogravimetric analysis was conducted on a NETZSCH simultaneous thermal analyzer (STA 409 PC Luxx) using O_2/N_2 (3:1) as flow gas.

Mechanical tests. The stress-strain curves were obtained from a custom designed setup consisting of a HengPing FA2004 balance with an accuracy of 0.1 mg and a micromanipulator with an accuracy of 10 μm for a stepwise compression of the sample. After loading (10 μm step length) to the desired strain, the BN foam was hold at the maximum compressive state for 30 s before unloading.

Permittivity measurement. The permittivity measurement was conducted on a precision impedance analyzer (HP 4294A). The capacitance between two parallel copper foil electrodes separated by air and BN foam was measured at 100 kHz respectively. The distance between the electrodes was controlled by a micromanipulator with an accuracy of 10 μm. The results are nearly independent to further increase in measuring frequency.

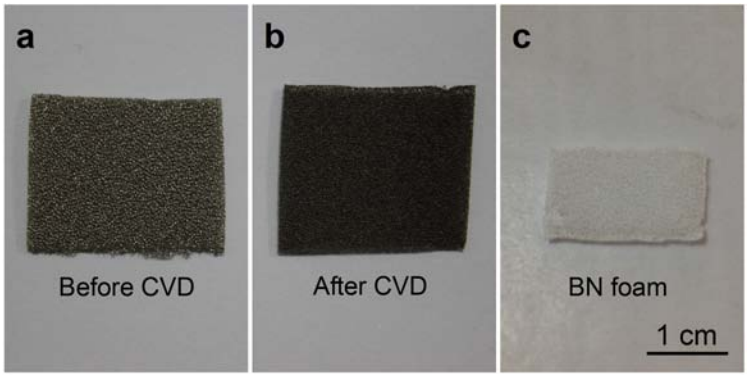

Figure S1 | Photographs of Ni foam (**a**), BN coated Ni foam (**b**) and free standing BN foam (**c**). After growth of BN, the color of the Ni foam changed from shiny white to dark gray. The BN foam shows white color after removing the Ni template.

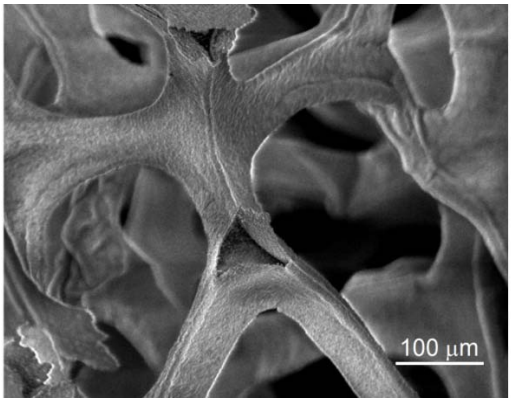

Figure S2 | A scanning electron micrograph of a cross section of the hollow tube-like branch.

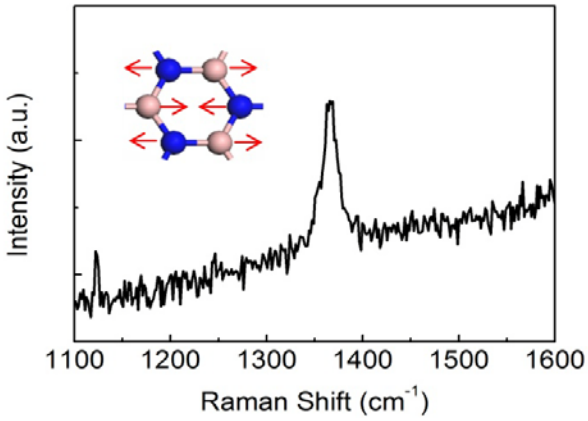

Figure S3 | Typical Raman spectra of the BN foam. The peak position is located at 1366 cm^{-1}, contributed to the phonon mode of BN illustrated in the insert.

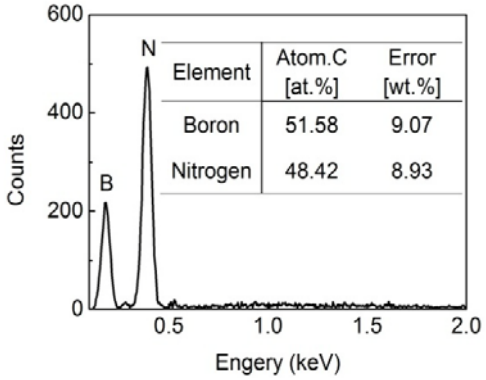

Figure S4 | Energy-dispersive X-ray spectrum of the BN foam. Only boron and nitrogen lines are visible, indicating the high purity of out sample.

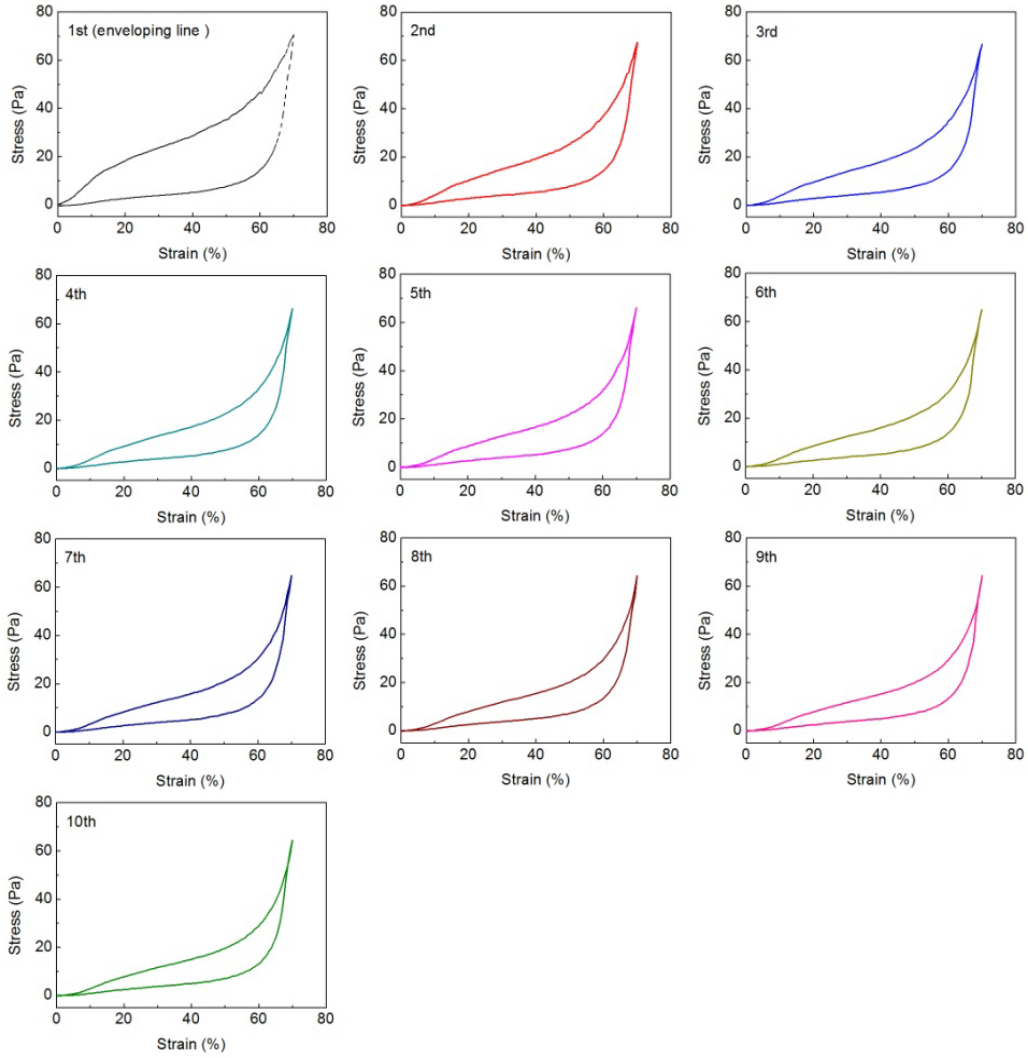

Figure S5 | Cyclic σ - ε curves for each of the first ten compression cycles.

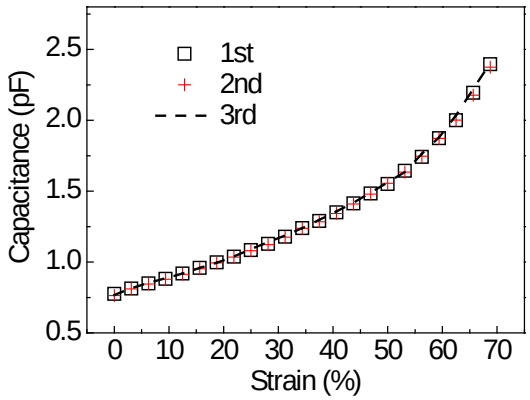

Figure S6 | Capacitance of the BN foam separated capcitor as a function of strain in two compressing cycles to 70% strain and the third cycle shown in Fig. 2A.

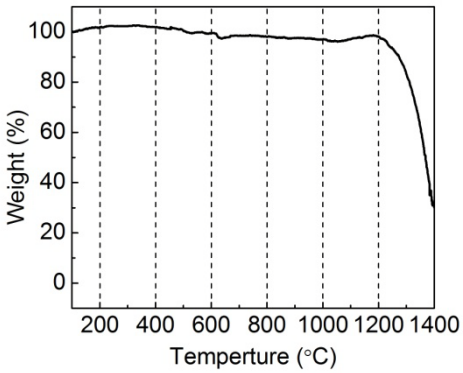

Figure S7 | Thermo-gravimetric analysis (ramp rate,10℃/min) of the BN foam in a mixture gas of N_2 and O_2 (N_2:O_2 = 1:3).

The sample was heated up to 1400°C at a rate of 10°C/min under a 40 sccm mixture gas flow of oxygen and nitrogen (O_2 : N_2 = 3 : 1). The weight of the BN foam almost keeps constant up to 1200°C. Weight loss occurs only when temperature increasing above 1200°C, and weight drops to 30 wt% at 1400°C as a result of BN oxidization. However, we found that slight collapse was introduced when the BN foam was heated above 1000 ºC, thus change in the mechanical characters should also happen.

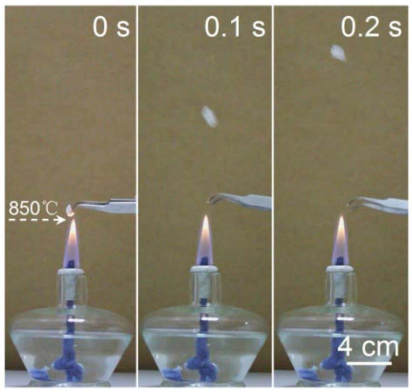

Figure S8 | A piece of BN foam can be lift-up but cannot be burn-up by the hot flame of a spirit lamp.

After released on the top of the outer zone of the flame, at which the temperature was measured around 850°C, a piece of the BN foam was lift-up for ~12 cm in a period of 0.2 s and then dropped gradually out of the flame. The flame induced heat air flow is accounted for the rising of the BN foam.

Table S1 Properties of ultralight materials

Material	Density (mg/cm^3)	Thermal stability	Resilience (Y/N)	E (Pa)	ε_{max}	Electric Conductivity	Ref.
BN Foam	~1.6	1200℃	Y	70~127	70%	Insulator	present
3D Graphene networks	~5	<600℃*	N	--	--	Conductor	7
	0.56~6.62		Y	130~31.7k	80%		9
	0.18~50		Y	15k	12%		6
CNT based	14		Y	~0.75M	80%		4
	8.8		N	~0.12M	--		
	5~10		Y	~0.14M	80%		5
Nickel microlattice	0.9~43	<400℃* oxidization	Y	0.7k~9M	50%		10
Silica aerogel	1.9~350	500℃	N	10^6~10^7 †	--	Insulator	30

* estimated by the thermal stability of the based materials

† For silica aerogels with density of 70-300 mg/cm^3 (Ref: Gronauer, M.; Kadur, A.; Fricke, J. *Aerogels*, **1986**, 6, 167-173)

In the fifth column, ε_{max} is the maximum compressive strain to which complete recovery can occur after unloading.