## Tunable ductility of a nano-network from few-layered graphene bonded with benzene: A molecular dynamics study

The detailed information of critical strains and stresses for all the models mentioned in the text are given in Table S1.

**Table S1** The critical strains and stresses in stretching direction of the samples under the strain rate of 0.1%/ps at different temperatures. "Pristine GN" means pristine graphene ribbon. "1<sup>st</sup>  $\sigma$ " is first peak value of x-stress, and "1<sup>st</sup>  $\varepsilon_c$ " is the first critical value of x-strain with respect to breakage of surface layers. "2<sup>nd</sup>  $\varepsilon_c$ " is the second critical value with respect to thorough breakage of all the layers.

Т	Pristine GN	P3C2 model				P3C3 model			
	ε <sub>c</sub>	1st o/GPa	$1^{st} \epsilon_c$	$2^{nd} \sigma/GPa$	$2^{nd}  \epsilon_c$	1 <sup>st</sup> σ/GPa	$1^{st} \epsilon_c$	$2^{nd} \sigma/GPa$	$2^{nd}  \epsilon_c$
8K	27.0%	33.98	19.1%	22.70	28.6%	28.2	19.1%	24.7	28.9%
50K	25.0%	32.69	19.1%	20.61	26.5%	28.0	19.0%	23.1	26.9%
100K	23.8%	31.62	18.5%	20.03	25.8%	27.0	19.2%	22.1	26.7%
200K	23.1%	29.46	17.4%	19.38	25.2%	25.3	18.1%	20.6	25.4%
300K	21.7%	26.22	16.4%	18.12	24.6%	22.4	16.6%	21.0	25.7%
500K	18.5%	19.66	13.6%	15.95	23.2%	14.2	12.9%	17.2	23.3%
Т	Pristine GN	P4C2 model				P4C3 model			
	ε <sub>c</sub>	1 <sup>st</sup> σ/GPa	$1^{st} \epsilon_c$	2 <sup>nd</sup> <i>o</i> /GPa	$2^{nd} \epsilon_c$	1 <sup>st</sup> σ/GPa	$1^{st} \epsilon_c$	2 <sup>nd</sup> <i>o</i> /GPa	$2^{nd} \epsilon_c$
8K	27.0%	26.2	18.4%	22.5	32.2%	20.2	17.4%	24.6	32.2%
50K	25.0%	26.3	19.2%	22.8	33.1%	19.5	18.7%	24.3	33.1%
100K	23.8%	25.2	18.2%	23.1	33.3%	18.0	17.3%	22.7	31.4%
200K	23.1%	22.8	16.7%	21.0	31.0%	15.4	16.5%	21.7	30.1%
300K	21.7%	18.7	14.5%	20.2	30.1%	13.9	14.9%	22.1	30.5%
500K	18.5%	16.1	12.8%	177	28.3%	12.1	13.0%	14.1	24.8%
		10.1	12.070	1111	20.070	12.1			
	Pristine GN	1011	P5C2	model	20.370		P5C3	model	
Т	$\frac{\text{Pristine GN}}{\epsilon_{c}}$	1 <sup>st</sup> σ/GPa	P5C2 1 <sup>st</sup> ε <sub>c</sub>	model 2 <sup>nd</sup> σ/GPa	$2^{nd} \varepsilon_c$	l <sup>st</sup> σ/GPa	P5C3 1 <sup>st</sup> ε <sub>c</sub>	model 2 <sup>nd</sup> σ/GPa	$2^{nd} \epsilon_c$
Т 8К	$\frac{\text{Pristine GN}}{\epsilon_{c}}$ 27.0%	1 <sup>st</sup> σ/GPa 22.4	P5C2 $1^{st} ε_c$ 19.2%	$\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ 23.3	$\frac{2^{nd} \varepsilon_c}{37.9\%}$	1 <sup>st</sup> σ/GPa 16.3	$\frac{P5C3}{1^{st} \varepsilon_c}$ 19.1%	model $2^{nd} \sigma/GPa$ 24.9	$\frac{2^{nd} \varepsilon_c}{37.6\%}$
T 8K 50K	Pristine GN ε <sub>c</sub> 27.0% 25.0%	1 <sup>st</sup> σ/GPa 22.4 21.7	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8%	model 2 <sup>nd</sup> σ/GPa 23.3 23.7	2 <sup>nd</sup> ε <sub>c</sub> 37.9% 37.7%	1 <sup>st</sup> σ/GPa 16.3 15.8	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0%	model 2 <sup>nd</sup> σ/GPa 24.9 25.2	2 <sup>nd</sup> ε <sub>c</sub> 37.6% 37.4%
T 8K 50K 100K	εc           27.0%           25.0%           23.8%	1 <sup>st</sup> <i>σ</i> /GPa 22.4 21.7 21.3	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5%	$     model     2nd \sigma/GPa     23.3     23.7     23.7     23.7     $	2 <sup>nd</sup> ε <sub>c</sub> 37.9% 37.7% 37.8%	1 <sup>st</sup> σ/GPa 16.3 15.8 15.5	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4%	$     model      2nd \sigma/GPa     24.9     25.2     24.6     $	2 <sup>nd</sup> ε <sub>c</sub> 37.6% 37.4% 36.8%
T 8K 50K 100K 200K	εc           27.0%           25.0%           23.8%           23.1%	1 <sup>st</sup> σ/GPa 22.4 21.7 21.3 20.1	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4%	model 2 <sup>nd</sup> σ/GPa 23.3 23.7 23.7 21.4	2 <sup>nd</sup> ε <sub>c</sub> 37.9% 37.7% 37.8% 35.9%	1 <sup>st</sup> σ/GPa 16.3 15.8 15.5 14.4	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0%	model 2 <sup>nd</sup> σ/GPa 24.9 25.2 24.6 23.9	2 <sup>nd</sup> ε <sub>c</sub> 37.6% 37.4% 36.8% 36.4%
T 8K 50K 100K 200K 300K	εc           27.0%           25.0%           23.8%           23.1%           21.7%	1 <sup>st</sup> <i>σ</i> /GPa 22.4 21.7 21.3 20.1 18.9	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1%	$     model     2nd \sigma/GPa     23.3     23.7     23.7     21.4     21.7 $	2 <sup>nd</sup> ε <sub>c</sub> 37.9%           37.7%           37.8%           35.9%           36.2%	1st σ/GPa           16.3           15.8           15.5           14.4           13.4	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6%	$     model     2nd \sigma/GPa     24.9     25.2     24.6     23.9     19.2     $	2 <sup>nd</sup> ε <sub>c</sub> 37.6% 37.4% 36.8% 36.4% 32.4%
T 8K 50K 100K 200K 300K 500K	Pristine GN           ε <sub>c</sub> 27.0%           25.0%           23.8%           23.1%           21.7%           18.5%	1 <sup>st</sup> <i>σ</i> /GPa 22.4 21.7 21.3 20.1 18.9 15.0	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6%	$     model     2nd \sigma/GPa     23.3     23.7     23.7     21.4     21.7     17.9 $	2 <sup>nd</sup> ε <sub>c</sub> 37.9%         37.7%         37.8%         35.9%         36.2%         33.1%	1st σ/GPa           16.3           15.8           15.5           14.4           13.4           11.5	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6% 12.0%	$     model     2nd \sigma/GPa     24.9     25.2     24.6     23.9     19.2     19.6 $	$\frac{2^{nd} \varepsilon_c}{37.6\%}$ 37.4% 36.8% 36.4% 32.4% 32.9%
T 8K 50K 100K 200K 300K 500K	Pristine GN           ε <sub>c</sub> 27.0%           25.0%           23.8%           23.1%           21.7%           18.5%           Pristine GN	1 <sup>st</sup> σ/GPa         22.4         21.7         21.3         20.1         18.9         15.0	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6% P6C2	$     \begin{array}{r} model \\             2^{nd}  \sigma/GPa \\             23.3 \\             23.7 \\             23.7 \\             21.4 \\             21.7 \\             17.9 \\             model         $	2nd εc         37.9%         37.7%         37.8%         35.9%         36.2%         33.1%	1st σ/GPa         16.3         15.8         15.5         14.4         13.4         11.5	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6% 12.0% P6C3	model 2 <sup>nd</sup> σ/GPa 24.9 25.2 24.6 23.9 19.2 19.6 model	2 <sup>nd</sup> ε <sub>c</sub> 37.6% 37.4% 36.8% 36.4% 32.4% 32.9%
T 8K 50K 100K 200K 300K 500K T	Pristine GN           ε <sub>c</sub> 27.0%           25.0%           23.8%           23.1%           21.7%           18.5%           Pristine GN           ε <sub>c</sub>	1 <sup>st</sup> σ/GPa 22.4 21.7 21.3 20.1 18.9 15.0	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6% P6C2 1 <sup>st</sup> ε <sub>c</sub>	$     \begin{array}{r} model \\             2^{nd}  \sigma/\text{GPa} \\             23.3 \\             23.7 \\             23.7 \\             21.4 \\             21.7 \\             17.9 \\             \hline             model \\             2^{nd}  \sigma/\text{GPa} \\             2^{nd}  \sigma$	$\frac{2^{nd} \varepsilon_{c}}{37.9\%}$ $\frac{37.7\%}{37.8\%}$ $\frac{35.9\%}{36.2\%}$ $\frac{33.1\%}{2^{nd} \varepsilon_{c}}$		P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6% 12.0% P6C3 1 <sup>st</sup> ε <sub>c</sub>	model $2^{nd} \sigma/GPa$ 24.9 25.2 24.6 23.9 19.2 19.6 model $2^{nd} \sigma/GPa$	$\frac{2^{nd} \varepsilon_{c}}{37.6\%}$ 37.4% 36.8% 36.4% 32.4% 32.9% 2 <sup>nd</sup> $\varepsilon_{c}$
T 8K 50K 100K 200K 300K 500K T 8K	$\begin{tabular}{ c c c c c } \hline Pristine GN \\ \hline $\epsilon_c$ \\ 27.0\% \\ 25.0\% \\ 23.8\% \\ 23.1\% \\ 23.1\% \\ 21.7\% \\ 18.5\% \\ \hline Pristine GN \\ \hline $\epsilon_c$ \\ 27.0\% \\ \hline \end{tabular}$	1 <sup>st</sup> σ/GPa 22.4 21.7 21.3 20.1 18.9 15.0 1 <sup>st</sup> σ/GPa 22.2	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6% P6C2 1 <sup>st</sup> ε <sub>c</sub> 18.7%	$     model     2nd \sigma/GPa     23.3     23.7     23.7     21.4     21.7     17.9     model     2nd \sigma/GPa     23.5     $	$   \begin{array}{r}     2^{nd} \ \varepsilon_c \\     37.9\% \\     37.7\% \\     37.8\% \\     35.9\% \\     36.2\% \\     33.1\% \\   \end{array} $	$     \begin{array}{r}       1^{\text{st}} \sigma/\text{GPa} \\       16.3 \\       15.8 \\       15.5 \\       14.4 \\       13.4 \\       11.5 \\       \hline       1^{\text{st}} \sigma/\text{GPa} \\       16.1     \end{array} $	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6% 12.0% P6C3 1 <sup>st</sup> ε <sub>c</sub> 18.5%	$\frac{model}{2^{nd} \sigma/GPa}$ 24.9 25.2 24.6 23.9 19.2 19.6 model 2^{nd} \sigma/GPa 23.3	$     \begin{array}{r}       2^{nd} \varepsilon_{c} \\       37.6\% \\       37.4\% \\       36.8\% \\       36.4\% \\       32.4\% \\       32.9\% \\       \hline       2^{nd} \varepsilon_{c} \\       39.6\% \\       \end{array} $
T 8K 50K 100K 200K 300K 500K T 8K 50K	Pristine GN           ε <sub>c</sub> 27.0%           25.0%           23.8%           23.1%           21.7%           18.5%           Pristine GN           ε <sub>c</sub> 27.0%           25.0%	1 <sup>st</sup> <i>σ</i> /GPa 22.4 21.7 21.3 20.1 18.9 15.0 1 <sup>st</sup> <i>σ</i> /GPa 22.2 21.8	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6% P6C2 1 <sup>st</sup> ε <sub>c</sub> 18.7% 18.4%	$\begin{array}{r} model \\ \hline 2^{nd} \ \sigma/GPa \\ \hline 23.3 \\ 23.7 \\ 23.7 \\ 21.4 \\ 21.7 \\ 17.9 \\ \hline model \\ \hline 2^{nd} \ \sigma/GPa \\ \hline 23.5 \\ 23.5 \\ \hline 23.5 \\ \hline 23.5 \\ \hline 23.5 \\ \hline \end{array}$	$   \begin{array}{r}     2^{nd} \ \varepsilon_c \\     37.9\% \\     37.7\% \\     37.8\% \\     35.9\% \\     36.2\% \\     33.1\% \\     \hline     2^{nd} \ \varepsilon_c \\     43.3\% \\     43.5\% \\   \end{array} $	$     \begin{array}{r}       1^{\text{st}} \sigma/\text{GPa} \\       16.3 \\       15.8 \\       15.5 \\       14.4 \\       13.4 \\       11.5 \\       \hline       1^{\text{st}} \sigma/\text{GPa} \\       \hline       16.1 \\       15.8 \\       \hline       15.8 \\       \hline       16.1 \\       15.8 \\       \hline       15.8 \\       16.1 \\       15.8 \\    $	P5C3 1 <sup>st</sup> ε <sub>c</sub> 19.1% 18.0% 17.4% 16.0% 14.6% 12.0% P6C3 1 <sup>st</sup> ε <sub>c</sub> 18.5% 18.5% 18.0%	$\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ 24.9 25.2 24.6 23.9 19.2 19.6 model 2^{\text{nd}} \sigma/\text{GPa} 23.3 23.8	$\frac{2^{nd} \varepsilon_{c}}{37.6\%}$ $37.4\%$ $36.8\%$ $36.4\%$ $32.4\%$ $32.9\%$ $\frac{2^{nd} \varepsilon_{c}}{39.6\%}$ $40.8\%$
T 8K 50K 100K 200K 300K 500K T 8K 50K 100K	$\begin{tabular}{ c c c c c } \hline Pristine GN \\ \hline $\epsilon_c$ \\ \hline $27.0\%$ \\ \hline $25.0\%$ \\ \hline $23.1\%$ \\ \hline $23.1\%$ \\ \hline $23.1\%$ \\ \hline $21.7\%$ \\ \hline $18.5\%$ \\ \hline \hline $Pristine GN$ \\ \hline $\epsilon_c$ \\ \hline $27.0\%$ \\ \hline $25.0\%$ \\ \hline $23.8\%$ \\ \hline \end{tabular}$	1 <sup>st</sup> σ/GPa 22.4 21.7 21.3 20.1 18.9 15.0 1 <sup>st</sup> σ/GPa 22.2 21.8 21.2	P5C2 1 <sup>st</sup> ε <sub>c</sub> 19.2% 17.8% 17.5% 16.4% 15.1% 11.6% P6C2 1 <sup>st</sup> ε <sub>c</sub> 18.7% 18.4% 17.6%	$     model     2^{nd} \sigma/GPa     23.3     23.7     23.7     21.4     21.7     17.9     model     2^{nd} \sigma/GPa     23.5     23.5     17.4 $	$     \begin{array}{r}       2^{nd} \ \varepsilon_c \\       37.9\% \\       37.7\% \\       37.8\% \\       35.9\% \\       36.2\% \\       33.1\% \\       \hline       2^{nd} \ \varepsilon_c \\       43.3\% \\       43.5\% \\       37.8\% \\       37.8\% \\   \end{array} $	$     \begin{array}{r}       1^{st} \sigma/\text{GPa} \\       16.3 \\       15.8 \\       15.5 \\       14.4 \\       13.4 \\       11.5 \\       \hline       1^{st} \sigma/\text{GPa} \\       16.1 \\       15.8 \\       15.0 \\       \hline       15.0 \\       \hline       1^{st} 5.0 \\       1^$	$\begin{array}{c} P5C3 \\ 1^{st} \varepsilon_{c} \\ 19.1\% \\ 18.0\% \\ 17.4\% \\ 16.0\% \\ 14.6\% \\ 12.0\% \\ \hline P6C3 \\ 1^{st} \varepsilon_{c} \\ 18.5\% \\ 18.0\% \\ 16.8\% \\ \end{array}$	$\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ 24.9 25.2 24.6 23.9 19.2 19.6 model 2^{\text{nd}} \sigma/\text{GPa} 23.3 23.8 23.9	$\frac{2^{nd} \varepsilon_{c}}{37.6\%}$ $37.6\%$ $37.4\%$ $36.8\%$ $36.4\%$ $32.4\%$ $32.9\%$ $\frac{2^{nd} \varepsilon_{c}}{39.6\%}$ $40.8\%$ $41.3\%$
T 8K 50K 100K 200K 300K 500K T 8K 50K 100K 200K	$\epsilon_c$ 27.0%           25.0%           23.8%           23.1%           21.7%           18.5%           Pristine GN $\epsilon_c$ 27.0%           23.1%           23.1%           23.1%	$\frac{1^{\text{st}} \sigma/\text{GPa}}{22.4}$ 21.7 21.3 20.1 18.9 15.0 1^{\text{st}} \sigma/\text{GPa} 22.2 21.8 21.2 20.0	$\begin{array}{c} P5C2 \\ \hline P5C2 \\ \hline 1^{st} \ \varepsilon_c \\ \hline 19.2\% \\ \hline 17.8\% \\ \hline 17.5\% \\ \hline 16.4\% \\ \hline 15.1\% \\ \hline 11.6\% \\ \hline \\ \hline P6C2 \\ \hline 1^{st} \ \varepsilon_c \\ \hline 18.7\% \\ \hline 18.4\% \\ \hline 17.6\% \\ \hline 16.2\% \\ \end{array}$	$\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ $23.3$ $23.7$ $23.7$ $21.4$ $21.7$ $17.9$ $\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ $23.5$ $23.5$ $17.4$ $21.7$	$     \begin{array}{r}       2^{nd} \ \varepsilon_c \\       37.9\% \\       37.7\% \\       37.8\% \\       35.9\% \\       36.2\% \\       33.1\% \\       \hline       2^{nd} \ \varepsilon_c \\       43.3\% \\       43.5\% \\       37.8\% \\       41.3\% \\       \end{array} $	$     \begin{array}{r}       1^{st} \sigma/\text{GPa} \\       16.3 \\       15.8 \\       15.5 \\       14.4 \\       13.4 \\       11.5 \\       \hline       1^{st} \sigma/\text{GPa} \\       16.1 \\       15.8 \\       15.0 \\       14.4 \\       14.4 \\       \end{array} $	$\begin{array}{c} P5C3\\ 1^{st} \ \varepsilon_c\\ 19.1\%\\ 18.0\%\\ 17.4\%\\ 16.0\%\\ 14.6\%\\ 12.0\%\\ \hline \\ P6C3\\ 1^{st} \ \varepsilon_c\\ 18.5\%\\ 18.0\%\\ 16.8\%\\ 15.9\%\\ \end{array}$	$\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ $24.9$ $25.2$ $24.6$ $23.9$ $19.2$ $19.6$ $\frac{\text{model}}{2^{\text{nd}} \sigma/\text{GPa}}$ $23.3$ $23.8$ $23.9$ $20.5$	$\frac{2^{nd} \varepsilon_{c}}{37.6\%}$ $37.4\%$ $36.8\%$ $36.4\%$ $32.4\%$ $32.9\%$ $\frac{2^{nd} \varepsilon_{c}}{39.6\%}$ $40.8\%$ $41.3\%$ $38.8\%$

500K	18.5%	16.1	12.6%	17.9	38.0%	10.6	11.1%	16.0	33.0%
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