

– Supplementary Information –

## Atomic Layer MoS<sub>2</sub>-Graphene van der Waals Heterostructure Nanomechanical Resonators

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**Table S1:** Frequency and Quality (*Q*) Factors of Atomic Layer Graphene, MoS<sub>2</sub> and  
Their Vertically Stacked Heterostructure Nanomechanical Resonators

1L MoS<sub>2</sub> / 2L Graphene Heterostructures

Diameter  $d \approx 0.75\mu\text{m}$

Device #	2L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	<i>f</i> (MHz)	<i>Q</i> Factor		<i>f</i> (MHz)	<i>Q</i> Factor		<i>f</i> (MHz)	<i>Q</i> Factor
1	119.1	181	1	28.5	18	1	51.4	30
2	130.2	270	2	40.2	18	2	48.4	18
			3	73.3	33	3	69.2	125
			4	37.9	24	4	66.7	77
Normal Distributed Mean Value	124.6±7.8	226±63		45.0±19.5	23±7		58.9±10.5	63±48

Diameter  $d \approx 1.00\mu\text{m}$

Device #	2L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	<i>f</i> (MHz)	<i>Q</i> Factor		<i>f</i> (MHz)	<i>Q</i> Factor		<i>f</i> (MHz)	<i>Q</i> Factor
1	50.7	22	1	36.3	28	1	69.2	39
2	135.8	123	2	88.0	19	2	81.2	75
3	70.2	97	3	54.1	39			
			4	53.2	51			
Normal Distributed Mean Value	85.4±44.8	81±51		57.9±51.7	34±14		75.2±8.5	57±25

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Diameter  $d \approx 1.25\mu\text{m}$

Device #	2L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	123.0	89	1	45.7	30	1	31.6	13
2	110.1	82	2	54.2	26	2	69.7	94
			3	52.2	22			
			4	42.6	39			
Normal Distributed Mean Value	116.6±9.1	86±5		48.7±5.4	29±8		50.6±26.8	53±57

Diameter  $d \approx 1.50\mu\text{m}$

Device #	2L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	135.6	185	1	47.8	24	1	70.4	95
2	126.7	173	2	26.9	29	2	70.3	106
3	72.6	89	3	33.8	44	3	70.2	96
4	123.3	183	4	32.5	44			
Normal Distributed Mean Value	114.6±28.4	158±46		35.3±9.3	35±10		70.3±0.1	99±6

1L MoS<sub>2</sub> / 3L Graphene Heterostructures

Diameter  $d \approx 0.75\mu\text{m}$

Device #	3L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	44.7	16	1	28.5	18	1	66.5	31
2	92.6	116	2	40.2	18	2	68.6	33
			3	73.3	33			
			4	37.9	24			
Normal Distributed Mean Value	68.7±33.9	66±70		45.0±19.5	23±7		67.6±1.5	32±1

Diameter  $d \approx 1.00\mu\text{m}$

Device #	3L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	60.6	12	1	36.3	28	1	52.0	47
2	102.0	29	2	88.0	19	2	52.2	29
3	63.1	52	3	54.1	39	3	105.2	62
4	104.2	127	4	53.2	51	4	66.8	30
						5	79.5	32
Normal Distributed Mean Value	82.5±23.9	55±51		57.9±51.7	34±14		71.1±22.2	40±14

Diameter  $d \approx 1.25\mu\text{m}$

Device #	3L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	103.9	91	1	45.7	30	1	81.4	84
2	81.8	56	2	54.2	26	2	52.9	28
3	61.8	67	3	52.2	22	3	75.5	23
4	129.7	197	4	42.6	39	4	78.7	27
						5	54.3	28
Normal Distributed Mean Value	94.3±29.2	103±65		48.7±5.4	29±8		68.4±14.1	38±26

Diameter  $d \approx 1.50\mu\text{m}$

Device #	3L Graphene		Device #	1L MoS <sub>2</sub> (CVD)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	45.3	19	1	47.8	24	1	67.6	83
2	63.0	53	2	26.9	29	2	70.6	79
			3	33.8	44	3	75.4	30
			4	32.5	44			
Normal Distributed Mean Value	54.2±12.5	36±24		35.3±9.3	35±10		71.2±3.9	64±30

## 1L MoS<sub>2</sub> / 4L Graphene Heterostructures

Diameter  $d \approx 0.75\mu\text{m}$

Device #	4L Graphene		Device #	1L MoS <sub>2</sub> (Exfoliated)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	71.9	76	1	24.2	23	1	29.7	215
2	109.8	118	2	43.7	113	2	93.2	27
			3	14.2	9			
			4	27.6	76			
			5	47.2	174			
Normal Distributed Mean Value	90.5±26.2	97±30		31.4±13.8	79±67		61.5±44.9	121±96

Diameter  $d \approx 1.00\mu\text{m}$

Device #	4L Graphene		Device #	1L MoS <sub>2</sub> (Exfoliated)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	72.3	45	1	33.6	104	1	33.4	122
2	92.8	132	2	42.5	95	2	63.4	32
3	93.9	203	3	31.4	37			
			4	31.9	31			
			5	29.6	35			
			6	46.5	71			
			7	43.9	154			
Normal Distributed Mean Value	86.3±12.2	127±79		37.5±7.0	75±46		48.4±21.2	77±64

Diameter  $d \approx 1.25\mu\text{m}$

Device #	4L Graphene		Device #	1L MoS <sub>2</sub> (Exfoliated)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	35.8	122	1	17.1	114	1	45.5	69
2	47.9	74	2	25.3	52	2	65.4	30
			3	26.9	21	3	64.7	39
			4	26.6	44	4	23.1	18
			5	35.1	51			
			6	34.5	137			
			7	7.55	8			
			8	35.5	157			
Normal Distributed Mean Value	41.9±8.6	98±35		26.1±9.8	73±56		49.7±20.0	39±22

Diameter  $d \approx 1.50\mu\text{m}$

Device #	4L Graphene		Device #	1L MoS <sub>2</sub> (Exfoliated)		Device #	Heterostructure	
	$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor		$f$ (MHz)	$Q$ Factor
1	47.9	132	1	18.8	81	1	43.1	32
2	72.4	52	2	23.9	25	2	46.5	30
3	51.8	61	3	51.2	68	3	56.8	36
			4	23.2	82			
			5	66.1	16			
			6	28.9	203			
Normal Distributed Mean Value	57.4±13.2	82±44		35.3±18.9	79±67		48.8±7.1	33±3