Supporting Information

Transfer and beyond: emerging strategies and trends in two-dimensional materials device fabrication

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Table S1. Scores of 6 evaluation criteria (ease of operation, cleanliness, transfer size, completeness, versatility, and multi-functionality) shown in the radar chart

Evaluation criterion		PMMA wet transfer method	Viscoelastic dry transfer method	Capillary force assisted hybrid method	Dielectric assisted method	SiN_x membranes pick up method	UV tape assisted hybrid method	Electrochemical stratification method	h-BN vdW pick up method	PC assisted transfer method
Ease of operation	Sacrificial layer	√	×	×	√	×	×	√	√	×
	tape	×	√	×	√	×	√	×	×	√
	Stamp	√	√	√	×	√	×	×	×	√
	Liquid solvent	√	×	×	√	√	√	√	√	×
	anneal	√	×	×	×	×	×	√	√	×
	Spending time	Hours	Minutes	Minutes	Minutes	Minutes	Hours	Minutes	1 Day	Half an hour
Cleanliness	Dielectric layer	PMMA	TRT/PDMS	PDMS	Sb_2O_3/PMMA/tape	SiN_x/Ta/Pt/Au	UV tape	PMMA	PDMS/PPC/h-BN	Glass/PDMS/PC/h-BN
	Evaluate	2	3	4	3	3	3	3	2	4
	Solvent residue	√	×	×	×	×	×	√	×	×
	Tape residue	×	√	×	×	×	√	×	×	×
	Scarified layer residue	√	√	×	√	×	×	√	×	×
	PDMS residue	×	√	×	×	×	×	×	×	×
	Evaluate	2	3	5	4	5	4	3	3	4
Transfer size	Scale	μm	μm		Wafer-scale	μm	Wafer-scale	Wafer-scale	μm	μm

Completeness	Evaluate	4	3	4	5	3	5	5	2	3
	wrinkle	√	×	×	×	×	×	√	×	×
	bubble	√	×	×	×	×	×	√	√	√
	breakage	√	√	×	√	×	×	√	×	×
Versatility	Evaluate	2	3	4	3	4	5	2	3	3
	CVD 2D materials	√	×	√	√	√	√	√	√	√
	Exfoliated 2D materials	√	√	√	√	√	√	√	√	√
	Evaporated/deposited thin film	√	×	√	×	√	√	√	√	√
	Transfer of Electrodes	√	√	√	×	×	√	√	√	√
Multi-functionalities	Evaluate	4	2	4	2	3	4	4	4	4
	Controlled Strain, controlled wrinkle, ease for twist easy integration with other structures, *etc*.	The operation accuracy is not high, which makes it difficult to apply techniques such as twist.	Some additional materials are needed to enhance adhesion and expand the functionality.	It can provide a high-quality interface and has excellent scalability.	It has a high-quality interface and can be patterned on dielectric films to achieve pattern transfer.	It has a high-quality interface, but there are certain requirements for the roughness of the substrate.	While providing a high-quality interface, it also has excellent scalability.	Can be combined with subsequent large-scale applications.	It can achieve high-quality interfaces, and h-BN can be used as the encapsulation layer.	Cannot completely control the existence of bubbles.
	Evaluate	2	2	4	3	3	4	3	4	3

Ref.	Ref [1]	Ref [2]	Ref [3]	Ref [4]	Ref [5]	Ref [6]	Ref [7]	Ref [8]	Ref [9]

Table S2.

Year	Transfer method	Device structure	Contaminants	Carrier mobility		Contact resistance (Ω) and Threshold voltage (V)	Subthreshold swing (SS)	Long-term cycling stability	Residue removing strategies	Ref
				Before treatment	After treatment					
2011	PMMA wet transfer **(Wet)**[10]	graphene FET	PMMA	1400 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	2700 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	NA	NA	NA	Vacuum anealing	[10]
2012	PMMA wet transfer **(Wet)**[11]	graphene FET	PMMA	1810 ± 710 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	3200 ± 670 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	500-750 Ω	NA	NA	300°C UHV anneal, and the in situ 80°C vacuum anneal	[11]
2016	Tape exfoliation **(Dry)**[12]	MoS_2 FET	Tape residue	NA	35 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	740 Ω·μm and -16V	NA	4-month air-stable	Vacuum anealing	[12]
2016	PMMA wet transfer CVD grown graphene **(Wet)**[13]	graphene FET	PMMA	Electron and hole mobility were 2141 and 2230 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	electron and hole mobility were 3770 and 4232 $cm^2 \cdot V^{-1} \cdot s^{-1}$	557.3 Ω to 125.4 Ω	NA	NA	laser exposure	[13]
2016	PVA-assisted transfer vs PMMA-assisted transfer **(Wet)**[14]	graphene FET	NA	PMMA assisted: electron and hole mobility were 1607 and	PVA assisted: electron and hole mobility were 3587 and 3800 $cm^2 \cdot V^{-1} \cdot s^{-1}$	NA	NA	NA	DI water	[14]

				1687 $cm^2 \cdot V^{-1} \cdot s^{-1}$,						
		MoS_2 FET	NA	PMMA assisted: electron were 1.1 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	PVA assisted: electron were 12 $cm^2 \cdot V^{-1} \cdot s^{-1}$	-6.5v	30mV/dec to 22mV/dec	NA		
2016	PVP+PVA-assisted transfer **(Dry)**[15]	MoS_2 FET	N/A	PMMA assisted: 3.0 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	PVA assisted: 9.0 $cm^2 \cdot V^{-1} \cdot s^{-1}$	NA	NA	NA	Vacuum anealing	[15]
2016	PPC/PDMS stamp assisted transfer **(Dry)**[16]	MoS_2 FET	Polymer residue	NA	25 $cm^2 \cdot V^{-1} \cdot s^{-1}$	75 Ω μm	120 mV/dec	NA	400°C annealing	[16]
2017	PMMA wet transfer CVD grown graphene **(Wet)**[17]	graphene FET	PMMA	electron and hole mobility were 2047.1 and 1440.9 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	electron and hole mobility were 2257.5 and 1500.3 $cm^2 \cdot V^{-1} \cdot s^{-1}$	NA	NA	NA	AFM cleaning	[17]
2019	gel tape exfoliation **(Dry)**[18]	MoS_2 FET	photoresist	~6.5 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	~100 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	~20.2 kΩ·μm to ~1 kΩ·μm	60mV/dec	NA	O_2 plasma	[18]
2019	Scotch tape method (CVD-grown WSe_2, and	WSe_2 FET	PMMA	32.5 ± 14.8 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	36.7 ± 16.5 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	+23.2V ± 1.3 to +20.2V ± 1.2	NA	NA	contact mode atomic force microscopy	[19]

	exfoliated MoS_2 and WSe_2) **(Wet)**[19]	MoS_2 FET		98.5 ± 17.9 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	100.6 ± 22.5 $cm^2 \cdot V^{-1} \cdot s^{-1}$,	-3.4V ± 5.5 to -6.1V ± 4.8	NA	NA	(AFM)	
2023	Ice-aided transfer (IAT) and ice stamp transfer (IST) **(Hybrid)**[20]	monolayer MoS_2 FET	NA	NA	24.3 $cm^2 \cdot V^{-1} \cdot s^{-1}$	NA	NA	6-month air stable	Ice-assisted transfer	[20]
2024	PPC assisted transfer **(Wet)**[21]	monolayer MoS_2 FET	0.08% PPC residue coverage	NA	19.2 $cm^2 \cdot V^{-1} \cdot s^{-1}$	78 Ω·μm and 5V	NA	NA	NA	[21]
2025	Capillary force-assisted PDMS stamp transfer **(Hybrid)**[22]	MoS_2 FET	NA	NA	15.62 $cm^2 \cdot V^{-1} \cdot s^{-1}$	-0.52V	150 mV/dec	NA	NA	[22]
2025	Hydrogenated diamond assisted transfer **(Dry)**[23]	monolayer MoS_2 FET	PDMS	NA	45 $cm^2 \cdot V^{-1} \cdot s^{-1}$	3V	NA	Minimal degradation (less than 10%) over a 3-day period of measurements	300℃ annealing for 1h to remove PDMS residue	[23]

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