Supporting Information

Atomic-Scale Stress Modulation of Nanolaminate for Micro-LED Encapsulation

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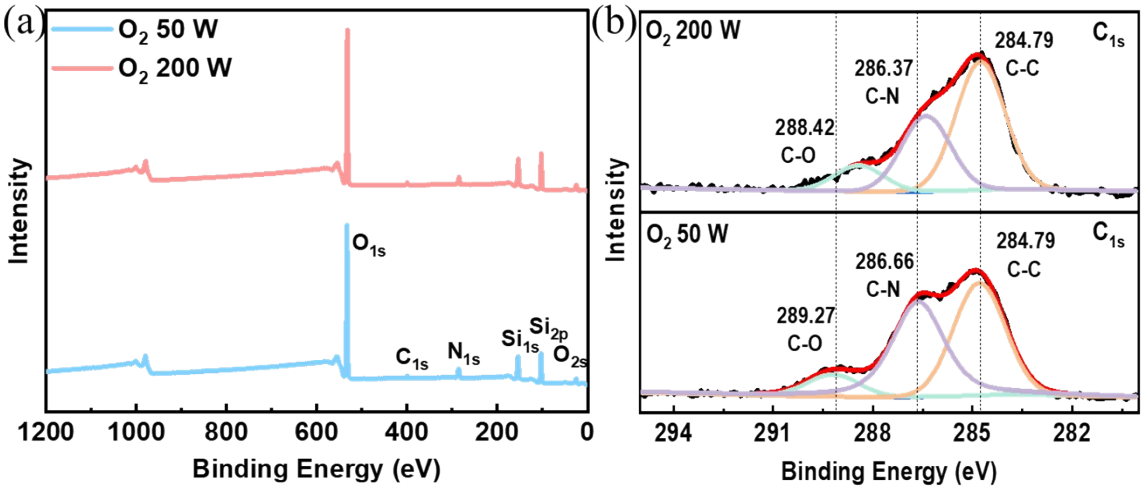

Figure S1. XPS spectra of SiO_2 film with various plasma power. (a) full spectrum. (b) C 1s.

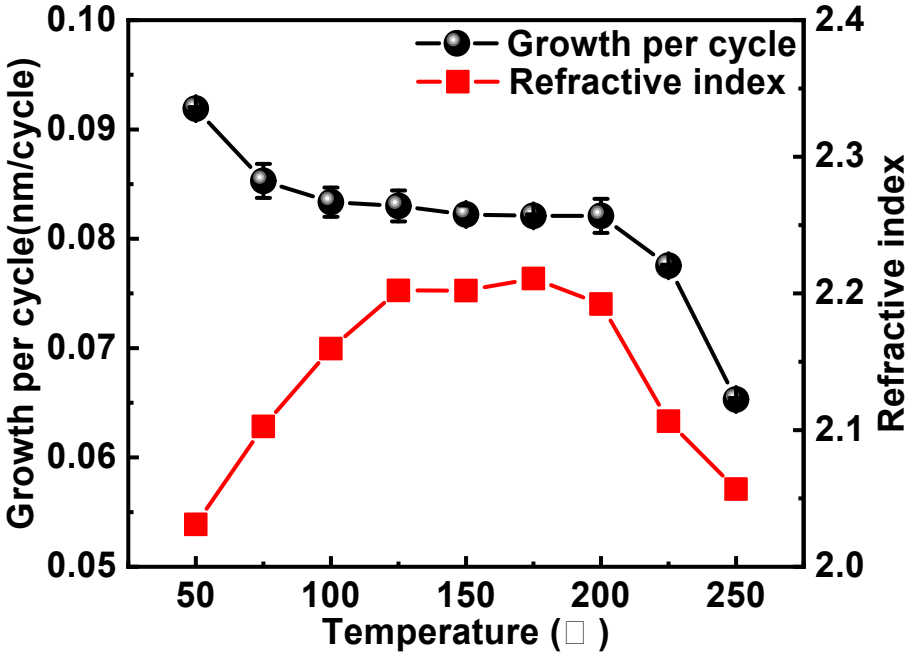

Figure S2. The effect of temperature on the growth per cycle and refractive index of SiO_2 thin film

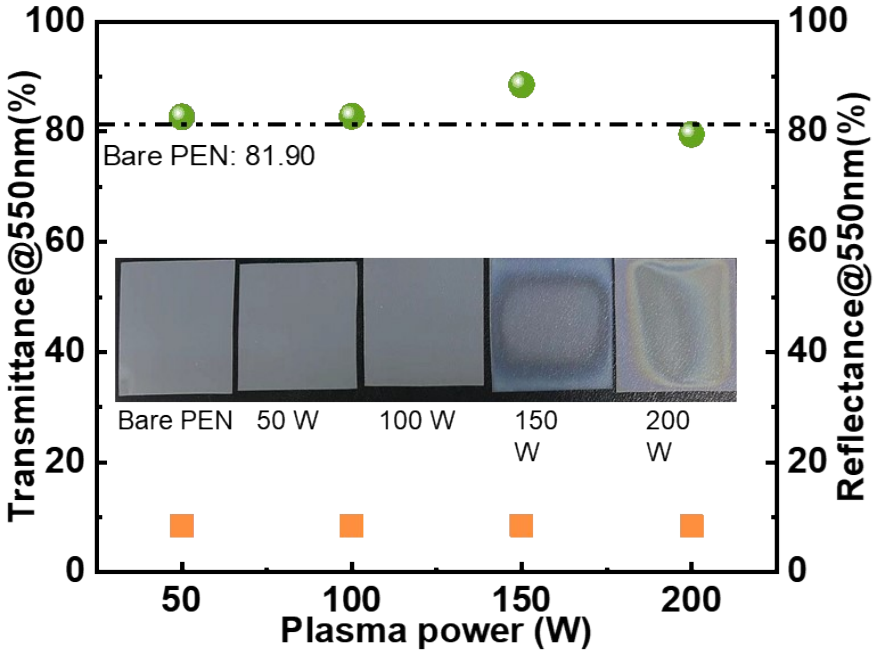

Figure S3. The effect of plasma power on the transmittance and reflectance of SiO_2 thin film

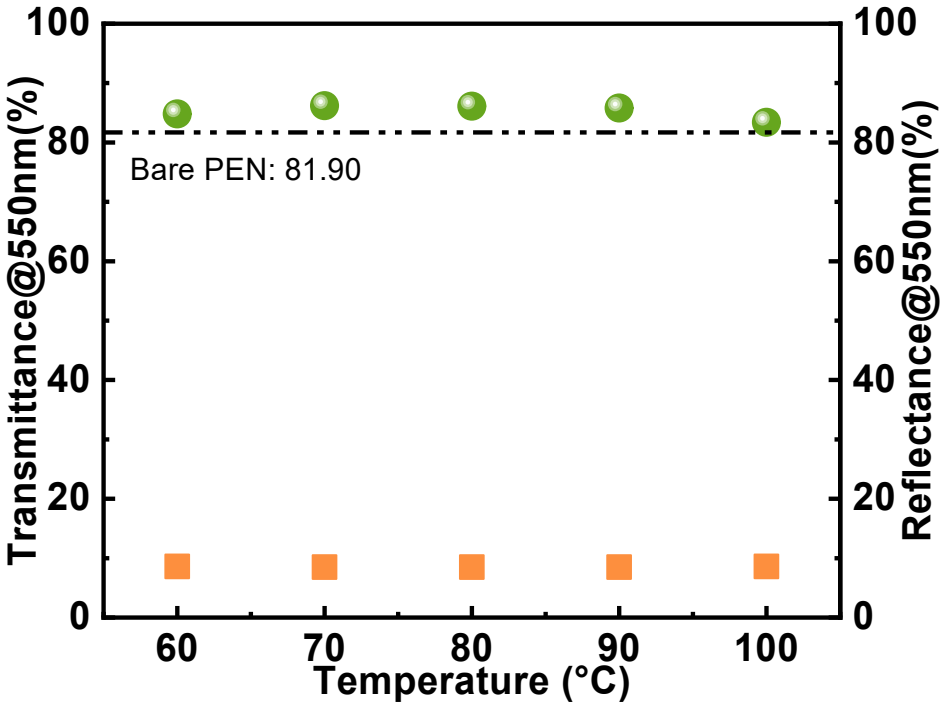

Figure S4. The effect of temperature on the transmittance and reflectance of SiO_2 thin film

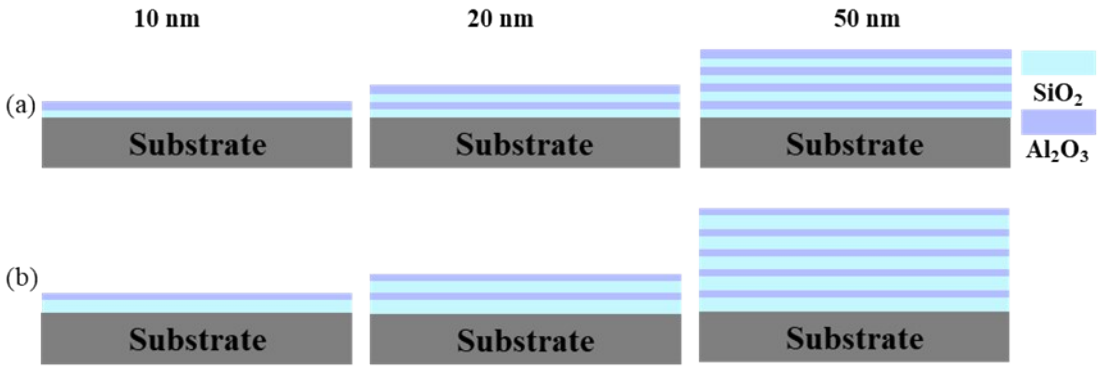

Figure S5. The structure of the nanolaminate with different pairs order. (a) $SA_{1/1.}$ (b) $SA_{2/1}$

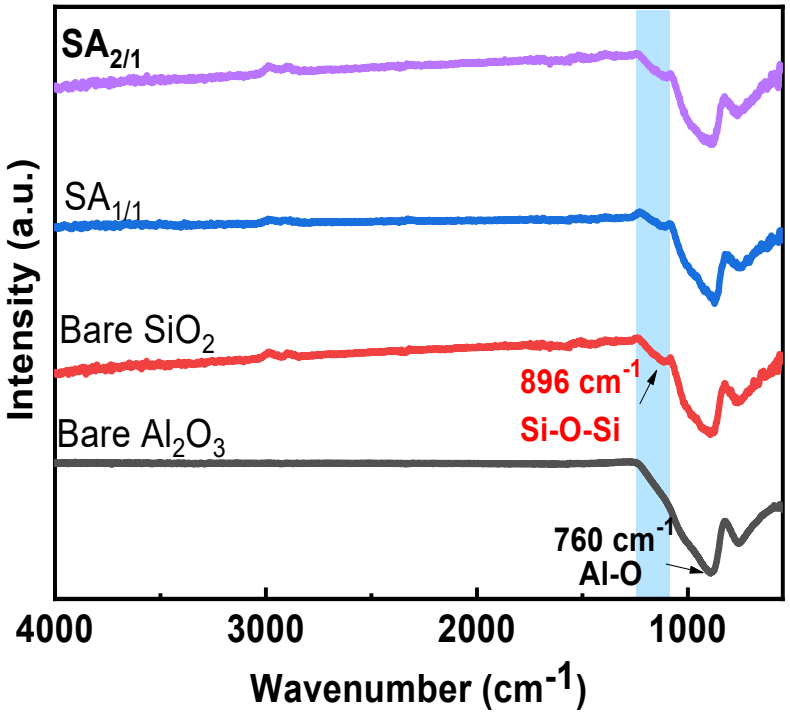

Figure S6. FTIR spectra of thin film (T-ALD Al_2O_3. PE-SiO_2. $SA_{1/1}$ and $SA_{2/1}$).

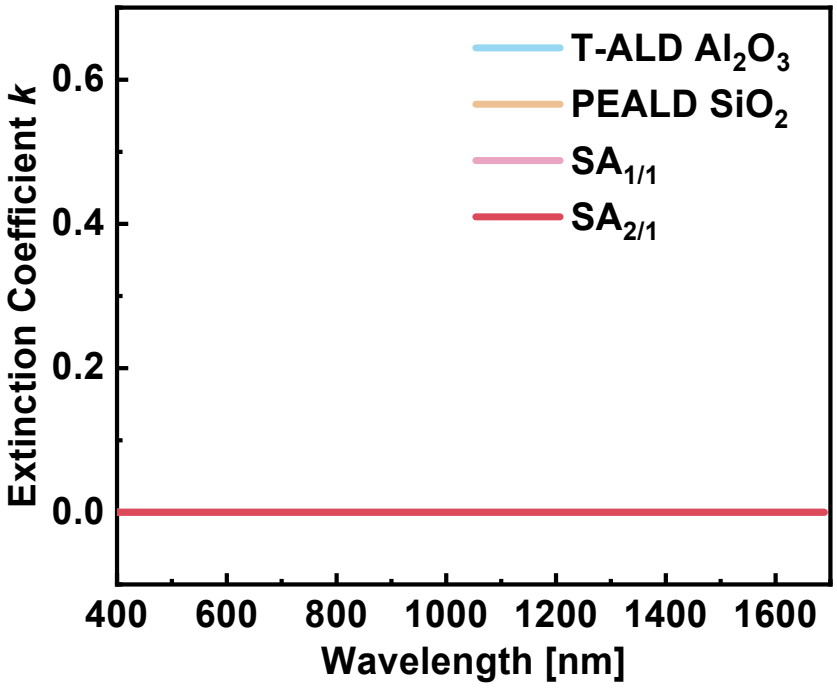

Figure S7. The extinction coefficient κ of SiO_2. Al_2O_3 thin film, $SA_{1/1}$, and $SA_{2/1}$

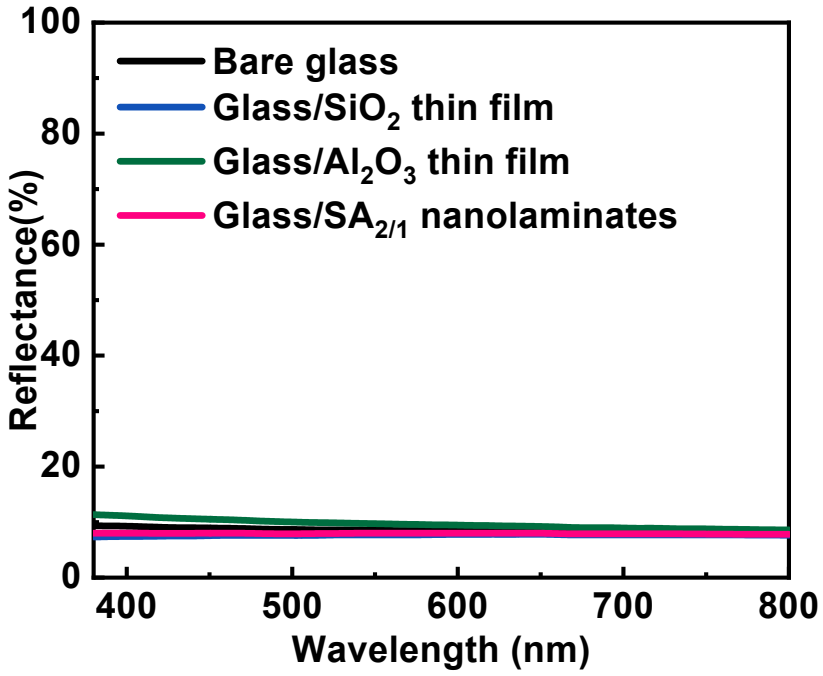

Figure S8. The reflectance of SiO_2. Al_2O_3 and $SA_{2/1}$ thin film

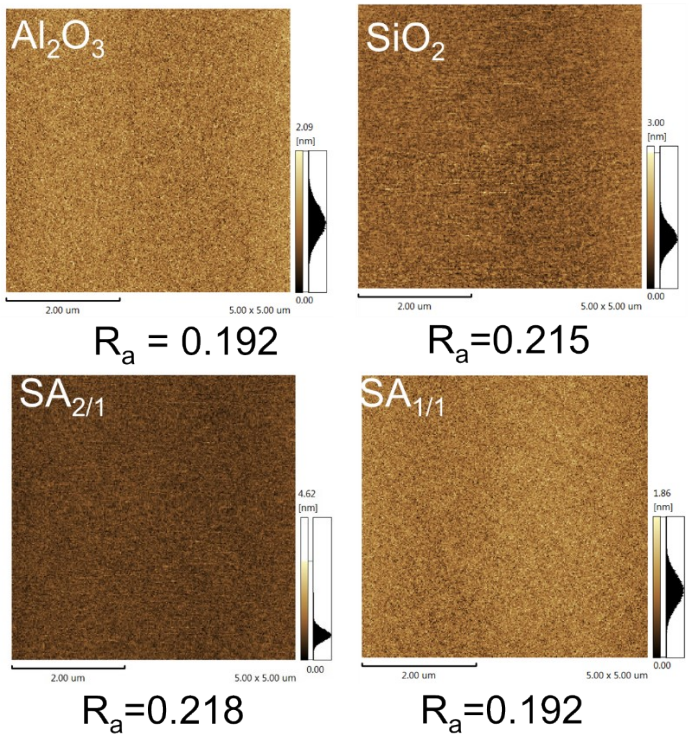

Figure S9. AFM of thin films. (a) SiO_2. (b) Al_2O_3 thin film. (c) $SA_{2/1}$ and (c) $SA_{1/1}$.

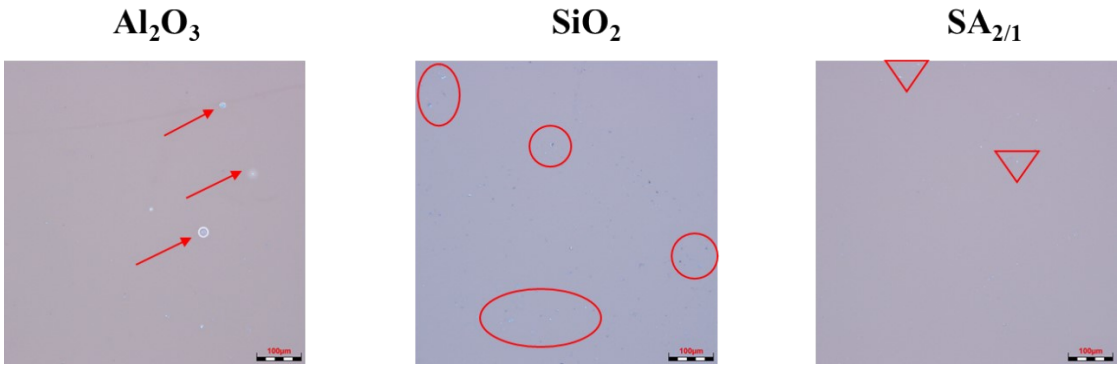

Figure S10. Ultra-depth 3D microscope image of thin films after aging condition (60°C/90% RH).

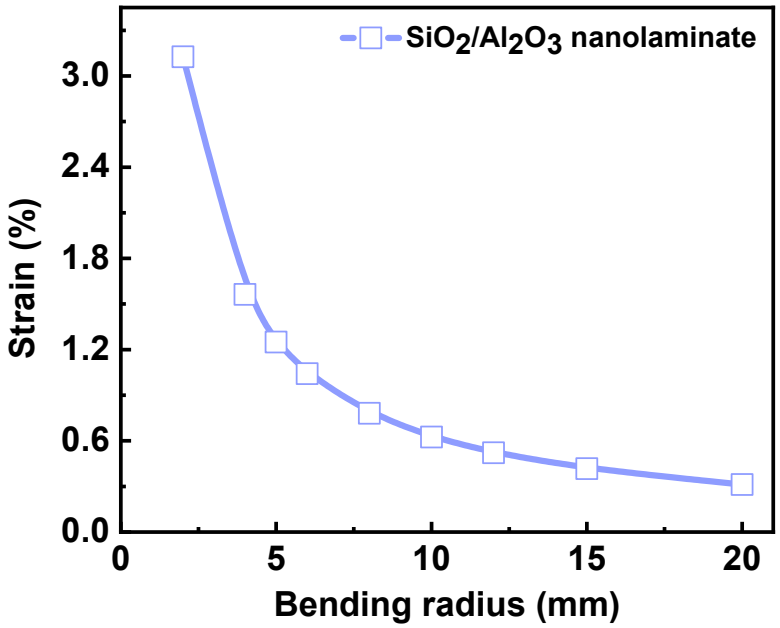

Figure S11. The correlation of the strain and bending radius.

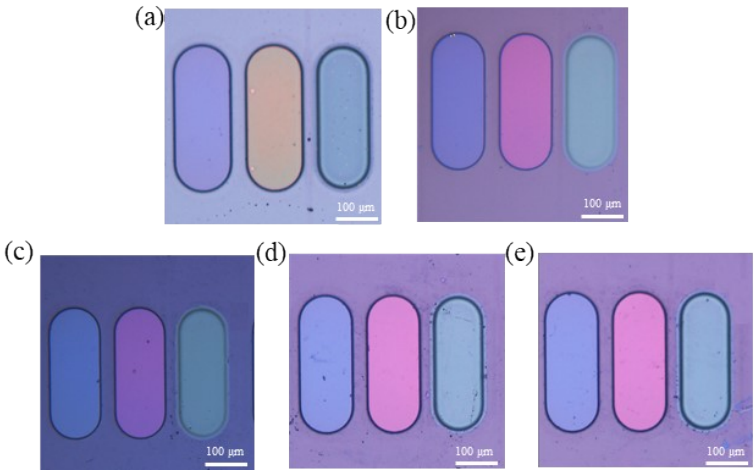

Figure S12. Ultra-depth 3D microscope image of (a) bare Micro-LED and Micro-LED with encapsulation of (b) PE-ALD-SiO_2. (c) T-ALD-Al_2O_3. (d) $SA_{1/1}$. and (e) $SA_{2/1}$

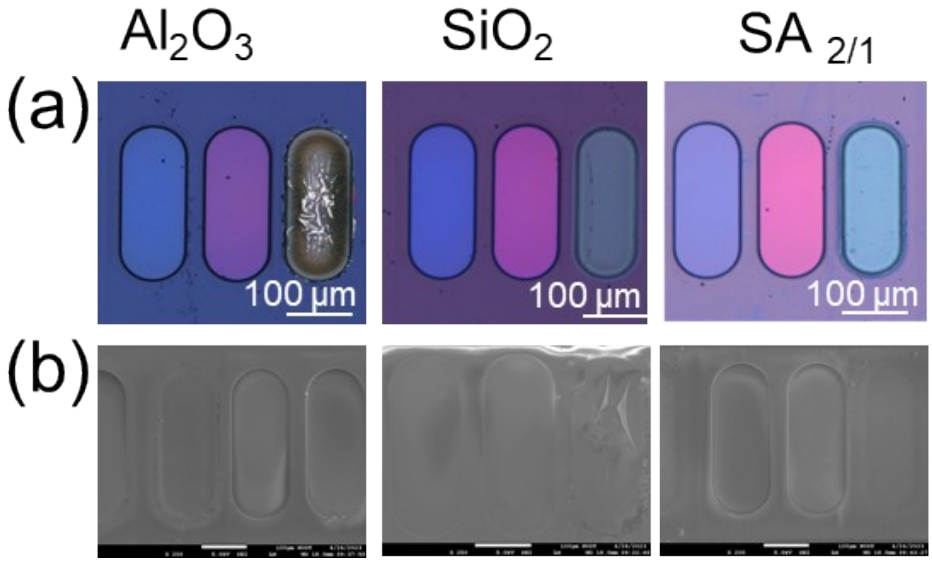

Figure S13. Ultra-depth 3D microscope image including bright field and SEM image for encapsulated Micro-LED after the deposition of 15 nm T-ALD Al_2O_3.

Table 1 Comparison with other literature on the residual stress of thin films

	Material	Process	Precursor	Process temperature (°C)	Thickness (nm)	Residual stress (MPa)	Ref.
	SiO_2/Al_2O_3	PEALD /ALD	TDMAS, O_2 plasma; TMA, O_2	100	10/20/50	<5	This work
Mono-layer	Polysilicon	CVD /annealing	SiH_4	>1000	2000	5	1
	SiNx	PECVD	SiH_4, NH_3, N_2	300	—	4	2
	Ir	MS	Ir	—	15.8	-2.89	3
	SiN_xH_y	PECVD	SiH_4, NH_3, N_2	125	680	5.1	4
	Al_2O_3	ALD	TMA, O_3/H_2O	500	60	50	5
	Al_2O_3	ALD	TMA, H_2O	300	100	180	6
	TiO_2	ALD	TDMAT, H_2O	40	30	40	7
Multi-film	$Al_2O_3/TiO_2/pV_3D_3$	ALD /iCVD	TMA,H_2O/ TDMAT, H_2O; PV3D3	300/40/—	115	~50	7
	HfO_2/SiO_2	PEALD	TDMAH, O_2 plasma/BDEAS, O_2plasma	100/50	2300	120	8
	$SiO_xN_y/SiO_2/SiO_xN_y$	PECVD /PEALD	SiH_4,mixture gas plasma/DIPAS, N_2O plasma	80	1000	-72	9
	HfO_2/Si	Evaporation	Hf	—	9100	-34.5	10
	Al_2O_3 /p(CHA-co-V_3D_3)	ALD/ iCVD	TMA, H_2O; CHA, V_3D_3, TBPO	90/35	200	22.5	11
	Al_2O_3 /Y_2O_3	ALD	TMA, H_2O/ Y- $(CpBu)_3$, H_2O	300	83	-40	12
	Al_2O_3 /SiO2	ALD/IBS	TMA, H_2O	200	628	38	13
	SAOLs /Al_2O_3	MLD/ALD	7- OTS, H_2O/ TMA, H_2O	80	152.5	-131.1	14

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