Electronic Supplementary Material (ESI) for Nanoscale

Supporting Information

Enhanced Optical Response of Hybridized VO_2/Graphene Films

Hyeongkeun Kim,†[a] Yena Kim,†[a,b] TaeYoung Kim,[a,c] A-Rang Jang,[d] Hu Young Jeong,[e] Seung-Ho Han,[a] Dae Ho Yoon,[b] Hyeon Suk Shin,[d] Dong Jae Bae,[f] Keun Soo Kim*[f] and Woo Seok Yang*[a]

[a]*Electronic Materials and Device Research Center, Korea Electronics Technology Institute, Seongnam 463-816, Korea. Fax: +82 31 789 7249; Tel: 82 31789 7256; E-mail : wsyang@keti.re.kr, faithkim99@keti.re.kr*
[b]*Department School of Advanced Materials Science and Engineering, Sungkyunkwan University, Suwon 440-746, Korea. E-mail: yenakim105@gmail.com*
[c]*Department of Mechanical Engineering and the Materials Science and Engineering Program The University of Texas at Austin, Austin TX 78712, USA*
[d]*Interdisciplinary School of Green Energy, Low Dimensional Carbon Materials Center, and KIER-UNIST Advanced Center for Energy, Ulsan National Institute of Science and Technology, Ulsan 689-805, Korea.*
[e]*UNIST Central Research Facilities (UCRF), Ulsan National Institutue of Science and Technology,Ulsan 689-798, Korea.*
[f]*Department of Physics and Graphene Research Institute, Sejong University, Seoul 143-747, Korea. E-mail: kskim2676@sejong.ac.kr*

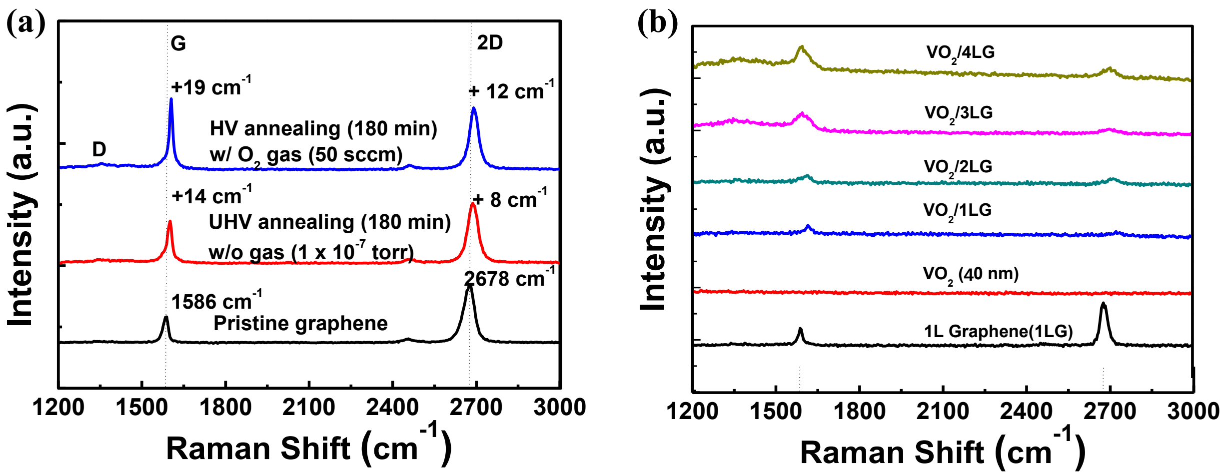

Fig. S1 Raman spectra of graphene films according to (a) annealing processes, (b) VO_2 growth.

Fig. S1 (a) shows raman spectra of graphene films under the different annealing conditions in ultra high vacuum (UHV) chamber. Eventhough, there is no D peak under the small amount of oxygen ambient and there is doping slightly because of the shifts of G and 2D peaks. (b) is raman spectras from the graphene and VO_2 thin film when it was on the graphene(0L~4L)/sapphire. As you can see here, the D peak can be seen almost invisible, silmilar with (a). One the other hand, The G and 2D peak of hybridize samples can be seen that an increase as increasing the number of graphene layers.

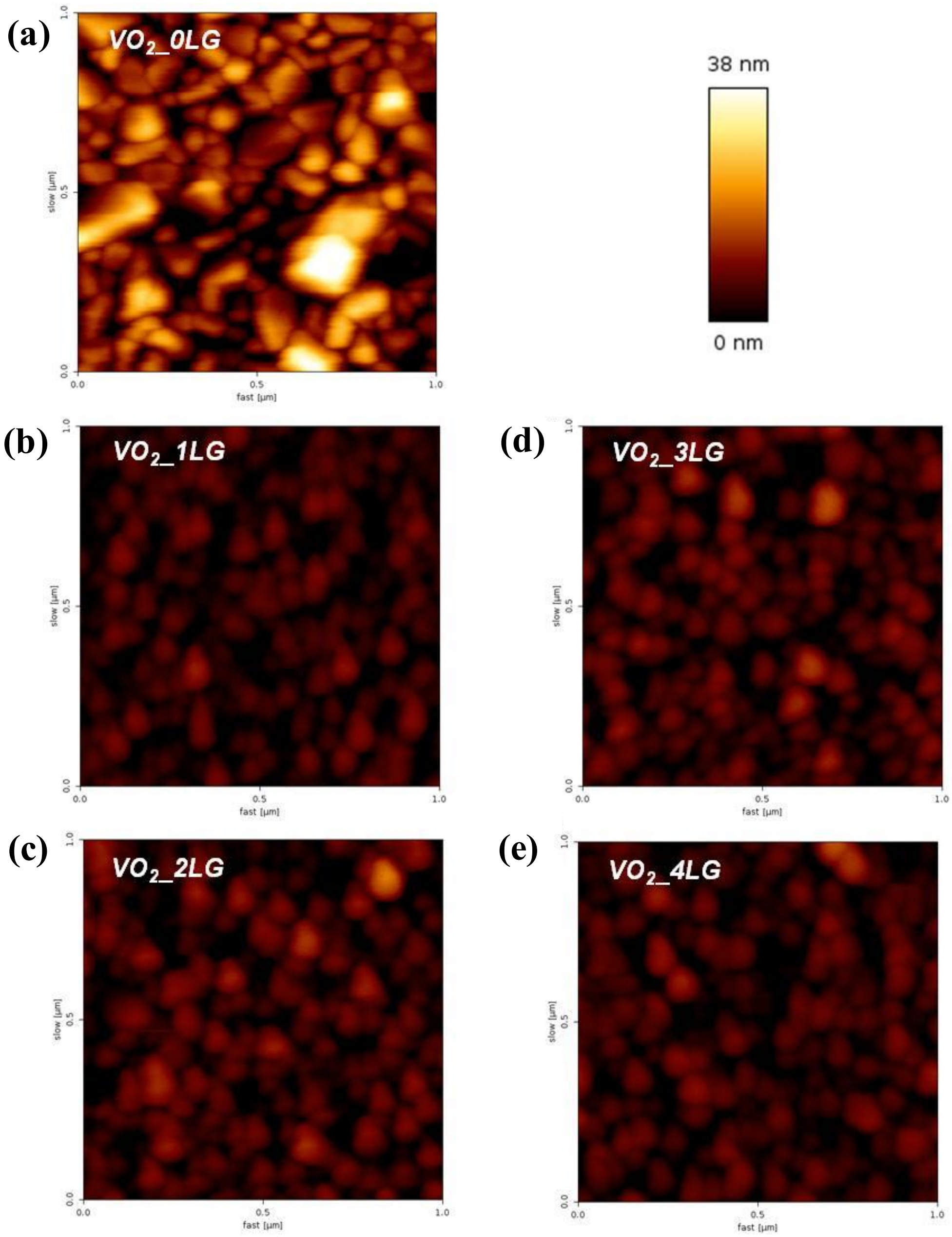

Fig. S2 AFM images of the graphene-supported VO_2. (VO_2 / x N layer/Sapphire)

According to the AFM analysis, the morphology of VO_2 thin films are signficantly different. In the canse of the VO_2 thin film on graphene(1L~4L)/ sapphire is much better uniformity for the grain size and vertical-profile(hightness) than the VO_2 thin films deposited on bare sapphire.

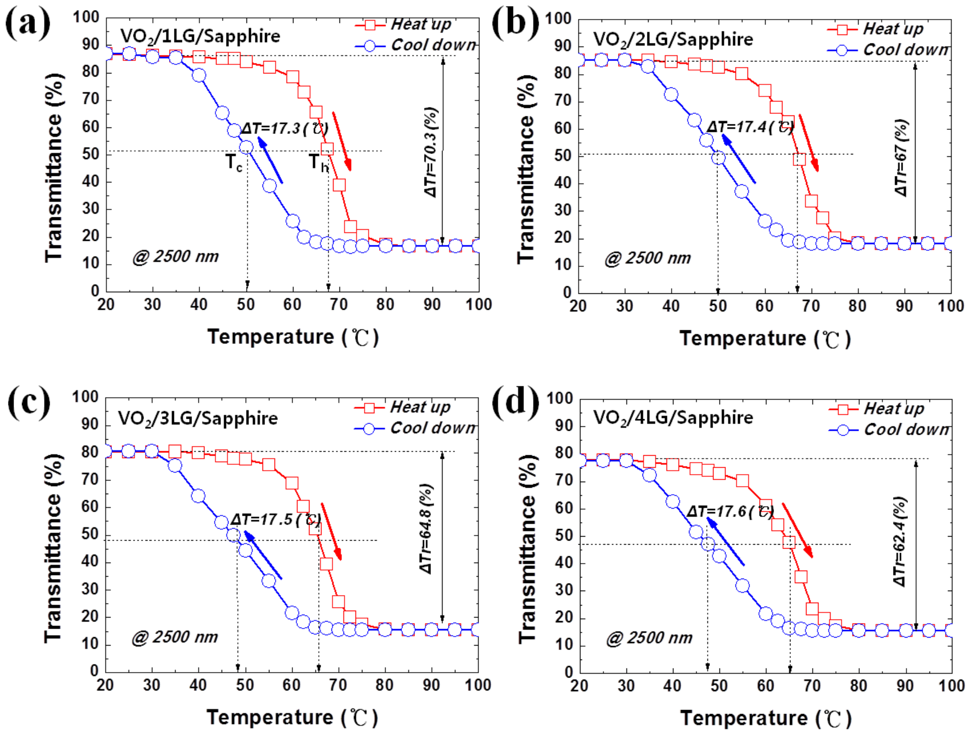

Fig. S3 Temperature dependence transmittance of the graphene-supported VO_2. (VO_2 / x N layer / Sapphire)

Fig. S3 is the temperature dependence IR transmittance of VO_2 thin film on graphene(1L~4L)/sapphire. According to the data, the critical phase transition temperature and the width of hysterisis are decreased as increasing the number of graphene-layers, respectively.

Tr_{max} : Transmittance of each samle at room temperature (20 ^{o}C), before phase transion.

Tr_{min} : Transmittance of each samle at high temperature(100 ^{o}C), after phase transion.

$Tr\_{half} = [(Tr\_{max} - Tr\_{min})/2] + Tr\_{min}$: Half point of transmittance-change, before and after phase transition (Reference transmittance for the estimation of T_c, T_h).

T_h : Phase transition temperature of hybridized VO_2/graphene samples for the heating process.

T_c : Phase transition temperature of hybridized VO_2/graphene samples for the cooling process.

Substrate (Sapphire)	Δ Tr (%)	T_h (°C)	T_m (°C)	T_c (°C)	ΔT (°C)	RMS (nm)
VO_2/0LG	58	71.8	62.2	52.7	19.1	8.6
VO_2/1LG	70.3	67.5	58.9	50.4	17.3	2.9
VO_2/2LG	67.0	66.9	58.2	49.5	17.4	3.2
VO_2/3LG	65.3	65.9	57.1	48.2	17.5	3.2
VO_2/4LG	62.4	65.0	56.1	47.2	17.6	2.9

Table. S1 Various optical properties of the graphene-supported VO_2.(VO_2 / x N layer / Sapphire)

Table S1 is from the analyzed values of Fig. S3 and S2 for each samples. According to the result, the phase transition temperature is decreased as increasing the number of graphene-layers, respectively. Regarding the mean phase transition temperature of VO_2 on 4L graphene sample is down to 56.1 °C and the surface morphology is also significantly different as there is graphene or not.

ΔTr (%): 100 Gap-value of maximum and minium transmittance for the sample.

$T_m = (T_h + T_c)/2$: Mean phase transition temperature of hybridized VO_2/graphene film on sapphire as a function of temperature.

$\Delta T = |T_h - T_c|$: hysteresis of phase transition temperature for hybridized VO_2/graphene film on sapphire depend on the heating and cooling process.

RMS: Relative values of surface morphology for each samples evaluated from Fig. S1.

Electronic Supplementary Material (ESI) for Nanoscale

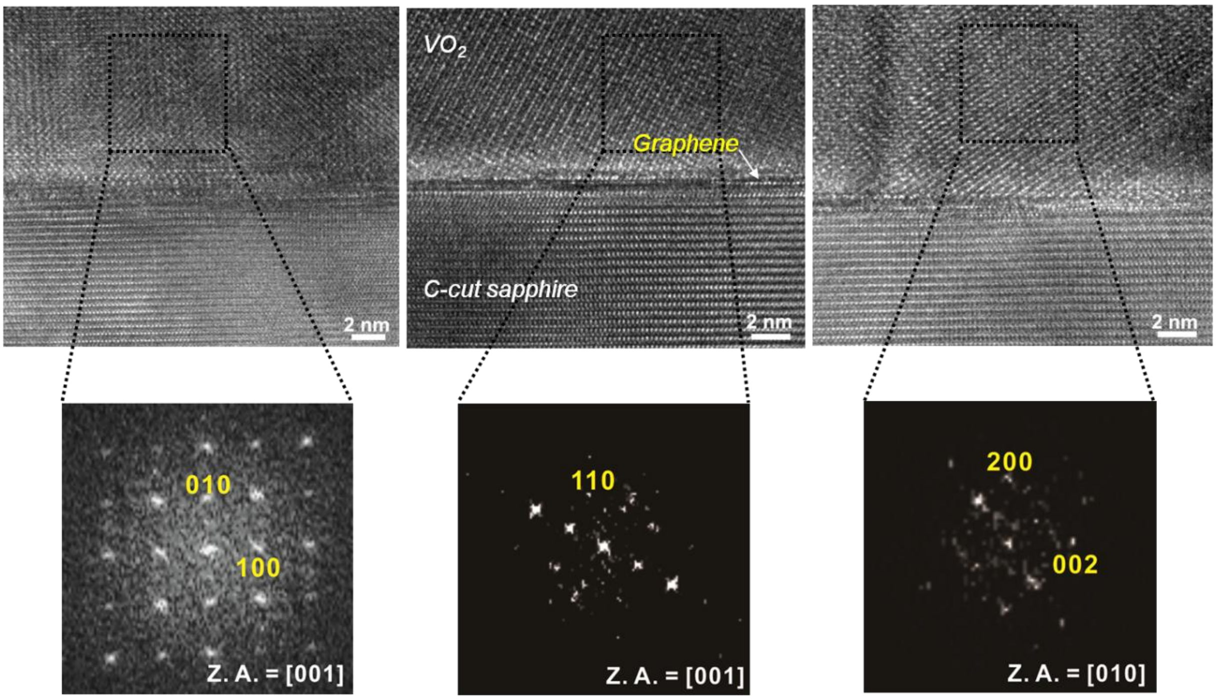

Fig. S4. High-resolution TEM images of the VO_2 films on graphene-supported sapphire substrate. (Various grains with different orientations could be observed)

VO_2 thin film on graphene-supported sapphire is no related with sapphire-orientation, as shown in above figure S4. The hybridized VO_2/graphene film on sapphire has a polycrystalline features, relatively.