*Thin Solid Films* • Volume 744 • 28 February 2022 • Article number 139092

**Document type**
Article

**Source type**
Journal

**ISSN**
00406090

**DOI**
10.1016/j.tsf.2022.139092

**Publisher**
Elsevier B.V.

**CODEN**
THSFA

**Original language**
English

View less

# Uniform growth of $MoS_2$ films using ultra-low $MoO_3$ precursor in one-step heating chemical vapor deposition

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Full text options

Funding details

## Abstract

In chemical vapor deposition (CVD), homogeneous molybdenum vapor concentration is important in synthesizing uniform thickness and large coverage of two-dimensional molybdenum disulfide (2D-$MoS_2$) films . Here, we synthesize few-layer $MoS_2$ films with uniform thickness and adequate coverage over 50 $mm^2$ size area using ultra-low molybdenum trioxide ($MoO_3$) precursor placed directly under a face-down silicon dioxide/silicon ($SiO_2$/Si) substrate in one-step heating CVD. The precursor mass is controlled by dispersing $MoO_3$ powder in ethanol ($C_2H_5OH$) and varying the volume of $MoO_3$/$C_2H_5OH$ solution coated on $SiO_2$/Si substrates into 10, 20 and 25 µL. Field emission scanning electron microscopy images reveal that 20 µL $MoO_3$/$C_2H_5OH$ solution produces ~93% area coverage of 2D-$MoS_2$ films . The average Raman spectra show the typical presence of $MoS_2$ peaks around 378.8 $cm^{-1}$ and 404 $cm^{-1}$ referring to the $E^1_{2g}$ and $A_{1g}$ modes, respectively. The difference between the two Raman modes for all samples is ~25 $cm^{-1}$, indicating few-layer $MoS_2$ films . The thickness of $MoS_2$ films is estimated at around 2.8 ± 0.44 nm and 3.2 ± 0.43 nm (~6 layers) using atomic force microscopy analysis. These findings suggest that ultra-low $MoO_3$ precursor is useful to produce uniform thickness and high coverage few-layer $MoS_2$ films using one-step heating CVD. © 2022 Elsevier B.V.

## Author keywords

Chemical vapor deposition ; Mo vapor concentration; Molybdenum disulfide; Molybdenum trioxide; One-step heating ; Uniform thickness

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Molybdenum trioxide

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## References (50)

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☐ 1 Singh, A.K., Kumar, P., Late, D.J., Kumar, A., Patel, S., Singh, J.

2D layered transition metal dichalcogenides ($MoS_2$): Synthesis, applications and theoretical aspects

(2018) *Applied Materials Today*, 13, pp. 242-270. Cited 68 times.
http://www.journals.elsevier.com/applied-materials-today/
doi: 10.1016/j.apmt.2018.09.003

View at Publisher

☐ 2 Samadi, M., Sarikhani, N., Zirak, M., Zhang, H., Zhang, H.-L., Moshfegh, A.Z.

Group 6 transition metal dichalcogenide nanomaterials: Synthesis, applications and future perspectives

(2018) *Nanoscale Horizons*, 3 (2), pp. 90-204. Cited 200 times.
http://www.rsc.org/journals-books-databases/about-journals/nanoscale-horizons/?id=8277
doi: 10.1039/c7nh00137a

View at Publisher

☐ 3 Chhowalla, M., Shin, H.S., Eda, G., Li, L.-J., Loh, K.P., Zhang, H.

The chemistry of two-dimensional layered transition metal dichalcogenide nanosheets

(2013) *Nature Chemistry*, 5 (4), pp. 263-275. Cited 6571 times.
doi: 10.1038/nchem.1589

View at Publisher

☐ 4 Mak, K.F., Lee, C., Hone, J., Shan, J., Heinz, T.F.

Atomically thin MoS2: A new direct-gap semiconductor (Open Access)

(2010) *Physical Review Letters*, 105 (13), art. no. 136805. Cited 10544 times.
http://oai.aps.org/oai?verb=GetRecord&Identifier=oai:aps.org:PhysRevLett.105.136805&metadataPrefix=oai_apsmeta_2
doi: 10.1103/PhysRevLett.105.136805

View at Publisher

☐ 5 Radisavljevic, B., Radenovic, A., Brivio, J., Giacometti, V., Kis, A.

Single-layer $MoS_2$ transistors (Open Access)

(2011) *Nature Nanotechnology*, 6 (3), pp. 147-150. Cited 10690 times.
http://www.nature.com/nnano/index.html
doi: 10.1038/nnano.2010.279

View at Publisher

☐ 6 Wang, Q.H., Kalantar-Zadeh, K., Kis, A., Coleman, J.N., Strano, M.S.

Electronics and optoelectronics of two-dimensional transition metal dichalcogenides (Open Access)

(2012) *Nature Nanotechnology*, 7 (11), pp. 699-712. Cited 10975 times.
http://www.nature.com/nnano/index.html
doi: 10.1038/nnano.2012.193

View at Publisher

☐ 7 Perkins, F.K., Friedman, A.L., Cobas, E., Campbell, P.M., Jernigan, G.G., Jonker, B.T.

Chemical vapor sensing with monolayer $MoS_2$

(2013) *Nano Letters*, 13 (2), pp. 668-673. Cited 869 times.
doi: 10.1021/nl3043079

View at Publisher

☐ 8 Lee, H.S., Min, S.-W., Park, M.K., Lee, Y.T., Jeon, P.J., Kim, J.H., Ryu, S., (...), Im, S.

$MoS_2$ nanosheets for top-gate nonvolatile memory transistor channel

(2012) *Small*, 8 (20), pp. 3111-3115. Cited 198 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)1613-6829
doi: 10.1002/smll.201200752

View at Publisher

☐ 9 Stephenson, T., Li, Z., Olsen, B., Mitlin, D.

Lithium ion battery applications of molybdenum disulfide ($MoS_2$) nanocomposites

(2014) *Energy and Environmental Science*, 7 (1), pp. 209-231. Cited 1035 times.
http://pubs.rsc.org/en/journals/journal/ee
doi: 10.1039/c3ee42591f

View at Publisher

☐ 10 Ng, K.E., Ooi, P.C., Shazni Mohammad Haniff, M.A., Goh, B.T., Dee, C.F., Chang, W.S., Razip Wee, M.F.M., (...), Mohamed, M.A.

Performance of all-solution-processed, durable 2D $MoS_2$ flakes–$BaTiO_3$ nanoparticles in polyvinylidene fluoride matrix nanogenerator devices using N-methyl-2-pyrrolidone polar solvent

(2020) *Journal of Alloys and Compounds*, 820, art. no. 153160. Cited 16 times.
https://www.journals.elsevier.com/journal-of-alloys-and-compounds
doi: 10.1016/j.jallcom.2019.153160

View at Publisher

☐ 11 Li, H., Wu, J., Yin, Z., Zhang, H.

Preparation and applications of mechanically exfoliated single-layer and multilayer $MoS_2$ and $WSe_2$ nanosheets

(2014) *Accounts of Chemical Research*, 47 (4), pp. 1067-1075. Cited 1055 times.
http://pubs.acs.org/journal/achre4
doi: 10.1021/ar4002312

View at Publisher

☐ 12 Magda, G.Z., Petõ, J., Dobrik, G., Hwang, C., Biró, L.P., Tapasztó, L.

Exfoliation of large-area transition metal chalcogenide single layers (Open Access)

(2015) *Scientific Reports*, 5, art. no. 14714. Cited 161 times.
www.nature.com/srep/index.html
doi: 10.1038/srep14714

View at Publisher

☐ 13 Fan, X., Xu, P., Zhou, D., Sun, Y., Li, Y.C., Nguyen, M.A.T., Terrones, M., (...), Mallouk, T.E.

Fast and Efficient Preparation of Exfoliated 2H $MoS_2$ Nanosheets by Sonication-Assisted Lithium Intercalation and Infrared Laser-Induced 1T to 2H Phase Reversion

(2015) *Nano Letters*, 15 (9), pp. 5956-5960. Cited 448 times.
http://pubs.acs.org/journal/nalefd
doi: 10.1021/acs.nanolett.5b02091

View at Publisher

☐ 14 Zhou, X., Xu, B., Lin, Z., Shu, D., Ma, L.

Hydrothermal synthesis of flower-like $MoS_2$nanospheres for electrochemical supercapacitors

(2014) *Journal of Nanoscience and Nanotechnology*, 14 (9), pp. 7250-7254. Cited 92 times.
http://docserver.ingentaconnect.com/deliver/connect/asp/15334880/v14n9/s107.pdf?expires=1411778238&id=79305185&titleid=4286&accname=Elsevier+BV&checksum=0EAA1B9DD405EFDA4549EDA34B845D42
doi: 10.1166/jnn.2014.8929

View at Publisher

☐ 15 Lee, Y.-H., Zhang, X.-Q., Zhang, W., Chang, M.-T., Lin, C.-T., Chang, K.-D., Yu, Y.-C., (...), Lin, T.-W.

Synthesis of large-area MoS $_2$ atomic layers with chemical vapor deposition (Open Access)

(2012) *Advanced Materials*, 24 (17), pp. 2320-2325. Cited 2593 times.
doi: 10.1002/adma.201104798

View at Publisher

☐ 16 Liu, K.-K., Zhang, W., Lee, Y.-H., Lin, Y.-C., Chang, M.-T., Su, C.-Y., Chang, C.-S., (...), Li, L.-J.

Growth of large-area and highly crystalline MoS $_2$ thin layers on insulating substrates (Open Access)

(2012) *Nano Letters*, 12 (3), pp. 1538-1544. Cited 1548 times.
doi: 10.1021/nl2043612

View at Publisher

☐ 17 Zhan, Y., Liu, Z., Najmaei, S., Ajayan, P.M., Lou, J.

Large-area vapor-phase growth and characterization of MoS $_2$ atomic layers on a SiO $_2$ substrate (Open Access)

(2012) *Small*, 8 (7), pp. 966-971. Cited 1414 times.
doi: 10.1002/smll.201102654

View at Publisher

☐ 18 Johari, M.H., Sirat, M.S., Mohamed, M.A., Wakayama, Y., Mohmad, A.R.

Effects of post-annealing on $MoS_2$ thin films synthesized by multi-step chemical vapor deposition (Open Access)

(2021) *Nanomaterials and Nanotechnology*, 11. Cited 3 times.
http://nax.sagepub.com/content/by/year
doi: 10.1177/1847980420981537

View at Publisher

☐ 19 Fauzi, F.B., Ismail, E., Syed Abu Bakar, S.N., Ismail, A.F., Mohamed, M.A., Md Din, M.F., Illias, S., (...), Ani, M.H.

The role of gas-phase dynamics in interfacial phenomena during few-layer graphene growth through atmospheric pressure chemical vapour deposition (Open Access)

(2020) *Physical Chemistry Chemical Physics*, 22 (6), pp. 3481-3489. Cited 6 times.
http://pubs.rsc.org/en/journals/journal/cp
doi: 10.1039/c9cp05346h

View at Publisher

☐ 20 Najmaei, S., Liu, Z., Zhou, W., Zou, X., Shi, G., Lei, S., Yakobson, B.I., (...), Lou, J.

Vapour phase growth and grain boundary structure of molybdenum disulphide atomic layers (Open Access)

(2013) *Nature Materials*, 12 (8), pp. 754-759. Cited 1384 times.
http://www.nature.com/nmat/
doi: 10.1038/nmat3673

View at Publisher

☐ 21 The Merck Index
(1983) . Cited 5120 times.
10th Edition Merck Co., Inc. Rahway, New Jersey 10th ed.

☐ 22 Lide, D.R.
CRC Handbook of Chemistry and Physics 88th 2007-2008
(2007) . Cited 59909 times.
88th ed. CRC Press, Taylor & Francis Boca Raton, FL

☐ 23 Jian, J., Chang, H., Xu, T.

Structure and properties of single-layer $MoS_2$ for nano-photoelectric devices (Open Access)

(2019) *Materials*, 12 (2), art. no. 198. Cited 14 times.
https://www.mdpi.com/1996-1944/12/2/198/pdf
doi: 10.3390/ma12020198

View at Publisher

☐ 24 Wang, W., Zeng, X., Wu, S., Zeng, Y., Hu, Y., Ding, J., Xu, S.

Effect of Mo concentration on shape and size of monolayer $MoS_2$ crystals by chemical vapor deposition

(2017) *Journal of Physics D: Applied Physics*, 50 (39), art. no. 395501. Cited 12 times.
http://iopscience.iop.org/article/10.1088/1361-6463/aa81ae/pdf
doi: 10.1088/1361-6463/aa81ae

View at Publisher

☐ 25 Johari, M.H., Sirat, M.S., Mohamed, M.A., Mohd Nasir, S.N.F., Mat Teridi, M.A., Mohmad, A.R.

Effects of Mo vapor concentration on the morphology of vertically standing $MoS_2$ nanoflakes

(2020) *Nanotechnology*, 31 (30), art. no. 305710. Cited 7 times.
https://iopscience.iop.org/article/10.1088/1361-6528/ab8666
doi: 10.1088/1361-6528/ab8666

View at Publisher

☐ 26 Nikpay, M.A., Mortazavi, S.Z., Reyhani, A., Elahi, S.M.

The effect of carrier gas flow rate on the growth of $MoS_2$ nanoflakes prepared by thermal chemical vapor deposition

(2018) *Optical and Quantum Electronics*, 50 (6), art. no. 252. Cited 3 times.
https://rd.springer.com/journal/11082
doi: 10.1007/s11082-018-1512-2

View at Publisher

☐ 27 Liu, H., Zhu, Y., Meng, Q., Lu, X., Kong, S., Huang, Z., Jiang, P., (...), Bao, X.

Role of the carrier gas flow rate in monolayer $MoS_2$ growth by modified chemical vapor deposition

(2017) *Nano Research*, 10 (2), pp. 643-651. Cited 31 times.
http://www.springer.com/materials/nanotechnology/journal/12274
doi: 10.1007/s12274-016-1323-3

View at Publisher

☐ 28 Rosman, N.N., Mohamad Yunus, R., Jeffery Minggu, L., Arifin, K., Kassim, M.B., Mohamed, M.A.

Vertical $MoS_2$on $SiO_2$/Si and graphene: Effect of surface morphology on photoelectrochemical properties

(2021) *Nanotechnology*, 32 (3), art. no. 035705. Cited 8 times.
https://iopscience.iop.org/article/10.1088/1361-6528/abbea9
doi: 10.1088/1361-6528/abbea9

View at Publisher

☐ 29 Lin, Z., Zhao, Y., Zhou, C., Zhong, R., Wang, X., Tsang, Y.H., Chai, Y.

Controllable Growth of Large-Size Crystalline $MoS_2$ and Resist-Free Transfer Assisted with a Cu Thin Film (Open Access)

(2015) *Scientific Reports*, 5, art. no. 18596. Cited 136 times.
www.nature.com/srep/index.html
doi: 10.1038/srep18596

View at Publisher

☐ 30 Withanage, S.S., Kalita, H., Chung, H.-S., Roy, T., Jung, Y., Khondaker, S.I.

Uniform Vapor-Pressure-Based Chemical Vapor Deposition Growth of $MoS_2$ Using $MoO_3$ Thin Film as a Precursor for Coevaporation (Open Access)

(2018) *ACS Omega*, 3 (12), pp. 18943-18949. Cited 17 times.
pubs.acs.org/journal/acsodf
doi: 10.1021/acsomega.8b02978

View at Publisher

31 Deng, S., Che, S., Debbarma, R., Berry, V.

Strain in a single wrinkle on an $MoS_2$ flake for in-plane realignment of band structure for enhanced photo-response

(2019) *Nanoscale*, 11 (2), pp. 504-511. Cited 17 times.
http://pubs.rsc.org/en/journals/journal/nr
doi: 10.1039/c8nr05884a

View at Publisher

32 Kim, S.J., Kim, D.W., Lim, J., Cho, S.-Y., Kim, S.O., Jung, H.-T.

Large-Area Buckled $MoS_2$ Films on the Graphene Substrate

(2016) *ACS Applied Materials and Interfaces*, 8 (21), pp. 13512-13519. Cited 33 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.6b01828

View at Publisher

33 Luo, S., Hao, G., Fan, Y., Kou, L., He, C., Qi, X., Tang, C., (...), Zhong, J.

Formation of ripples in atomically thin $MoS_2$ and local strain engineering of electrostatic properties

(2015) *Nanotechnology*, 26 (10), art. no. 105705. Cited 68 times.
http://iopscience.iop.org/0957-4484/26/10/105705/pdf/0957-4484_26_10_105705.pdf
doi: 10.1088/0957-4484/26/10/105705

View at Publisher

34 Zhou, D., Shu, H., Hu, C., Jiang, L., Liang, P., Chen, X.

Unveiling the Growth Mechanism of $MoS_2$ with Chemical Vapor Deposition: From Two-Dimensional Planar Nucleation to Self-Seeding Nucleation

(2018) *Crystal Growth and Design*, 18 (2), pp. 1012-1019. Cited 53 times.
http://pubs.acs.org/journal/cgdefu
doi: 10.1021/acs.cgd.7b01486

View at Publisher

35 Cain, J.D., Shi, F., Wu, J., Dravid, V.P.

Growth Mechanism of Transition Metal Dichalcogenide Monolayers: The Role of Self-Seeding Fullerene Nuclei

(2016) *ACS Nano*, 10 (5), pp. 5440-5445. Cited 128 times.
http://pubs.acs.org/journal/ancac3
doi: 10.1021/acsnano.6b01705

View at Publisher

36 Pondick, J.V., Woods, J.M., Xing, J., Zhou, Y., Cha, J.J.

Stepwise Sulfurization from $MoO_3$ to $MoS_2$ via Chemical Vapor Deposition

(2018) *ACS Applied Nano Materials*, 1 (10), pp. 5655-5661. Cited 49 times.
https://pubs.acs.org/journal/aanmf6
doi: 10.1021/acsanm.8b01266

View at Publisher

37 Molina-Sánchez, A., Wirtz, L.

Phonons in single-layer and few-layer $MoS_2$ and $WS_2$
(Open Access)

(2011) *Physical Review B - Condensed Matter and Materials Physics*, 84 (15), art. no. 155413. Cited 1019 times.
http://oai.aps.org/filefetch?identifier=10.1103/PhysRevB.84.155413&component=fulltext&description=markup&format=xml
doi: 10.1103/PhysRevB.84.155413

View at Publisher

38 Lee, C., Yan, H., Brus, L.E., Heinz, T.F., Hone, J., Ryu, S.

Anomalous lattice vibrations of single- and few-layer $MoS_2$
(Open Access)

(2010) *ACS Nano*, 4 (5), pp. 2695-2700. Cited 3350 times.
doi: 10.1021/nn1003937

View at Publisher

39 Wang, S., Pacios, M., Bhaskaran, H., Warner, J.H.

Substrate control for large area continuous films of monolayer $MoS_2$ by atmospheric pressure chemical vapor deposition

(2016) *Nanotechnology*, 27 (8), art. no. 085604. Cited 67 times.
http://iopscience.iop.org/article/10.1088/0957-4484/27/8/085604/pdf
doi: 10.1088/0957-4484/27/8/085604

View at Publisher

40 Li, H., Zhang, Q., Yap, C.C.R., Tay, B.K., Edwin, T.H.T., Olivier, A., Baillargeat, D.

From bulk to monolayer $MoS_2$: Evolution of Raman scattering

(2012) *Advanced Functional Materials*, 22 (7), pp. 1385-1390. Cited 2727 times.
doi: 10.1002/adfm.201102111

View at Publisher

41 Placidi, M., Dimitrievska, M., Izquierdo-Roca, V., Fontané, X., Castellanos-Gomez, A., Pérez-Tomás, A., Mestres, N., (...), Pérez-Rodríguez, A.

Multiwavelength excitation Raman scattering analysis of bulk and two-dimensional $MoS_2$: Vibrational properties of atomically thin $MoS_2$ layers (Open Access)

(2015) *2D Materials*, 2 (3), art. no. 035006. Cited 72 times.
http://iopscience.iop.org/2053-1583/
doi: 10.1088/2053-1583/2/3/035006

View at Publisher

42 Tan, S.M., Ambrosi, A., Pumera, M.
(2015) , pp. 7170-7178.
Pristine Basal- and Edge-Plane-Oriented Molybdenite MoS2 Exhibiting Highly Anisotropic Properties

☐ 43 Chen, F., Su, W.
The effect of the experimental parameters on the growth of $MoS_2$ flakes

(2018) *CrystEngComm*, 20 (33), pp. 4823-4830. Cited 16 times.
http://pubs.rsc.org/en/journals/journal/ce
doi: 10.1039/c8ce00733k

View at Publisher

☐ 44 Shi, Y., Zhang, H., Chang, W.-H., Shin, H.S., Li, L.-J.
Synthesis and structure of two-dimensional transition-metal dichalcogenides (Open Access)

(2015) *MRS Bulletin*, 40 (7), pp. 566-576. Cited 30 times.
http://journals.cambridge.org/MRS
doi: 10.1557/mrs.2015.121

View at Publisher

☐ 45 Addou, R., Colombo, L., Wallace, R.M.
Surface Defects on Natural $MoS_2$

(2015) *ACS Applied Materials and Interfaces*, 7 (22), pp. 11921-11929. Cited 235 times.
http://pubs.acs.org/journal/aamick
doi: 10.1021/acsami.5b01778

View at Publisher

☐ 46 Zhu, Z., Zhan, S., Zhang, J., Jiang, G., Yi, M., Wen, J.
Influence of growth temperature on $MoS_2$ synthesis by chemical vapor deposition

(2019) *Materials Research Express*, 6 (9), art. no. 095011. Cited 6 times.
https://iopscience.iop.org/article/10.1088/2053-1591/ab2c19/pdf
doi: 10.1088/2053-1591/ab2c19

View at Publisher

☐ 47 Yin, H., Zhang, X., Lu, J., Geng, X., Wan, Y., Wu, M., Yang, P.
Substrate effects on the CVD growth of $MoS_2$ and $WS_2$

(2020) *Journal of Materials Science*, 55 (3), pp. 990-996. Cited 24 times.
www.springer.com/journal/10853
doi: 10.1007/s10853-019-03993-9

View at Publisher

☐ 48 Jo, S., Jung, J.-W., Baik, J., Kang, J.-W., Park, I.-K., Bae, T.-S., Chung, H.-S., (...), Cho, C.-H.
Surface-diffusion-limited growth of atomically thin $WS_2$ crystals from core-shell nuclei (Open Access)

(2019) *Nanoscale*, 11 (18), pp. 8706-8714. Cited 11 times.
http://pubs.rsc.org/en/journals/journal/nr
doi: 10.1039/c9nr01594a

View at Publisher

49 Withanage, S.S., Khondaker, S.I.

CVD Growth of Monolayer $MoS_2$ on Sapphire Substrates by using MoO3 Thin Films as a Precursor for Co-Evaporation

(2019) *MRS Advances*, 4 (10), pp. 587-592. Cited 5 times.
https://www.cambridge.org/core/journals/mrs-advances
doi: 10.1557/adv.2018.657

View at Publisher

50 Ardahe, M., Hantehzadeh, M.R., Ghoranneviss, M.

Effect of Growth Temperature on Physical Properties of $MoS_2$ Thin Films Synthesized by CVD

(2020) *Journal of Electronic Materials*, 49 (2), pp. 1002-1008. Cited 9 times.
https://rd.springer.com/journal/11664
doi: 10.1007/s11664-019-07796-1

View at Publisher

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