# PENGARUH MASSA $CuCl_2$ YANG DITAMBAHKAN DALAM SINTESIS $Ti_3C_2$ MENGGUNAKAN METODE *MOLTEN SALT-SHIELDED SYNTHESIS* (MS3) TERHADAP KARAKTERISTIK MATERIAL

**SKRIPSI**

Diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar Sarjana Sains
Program Studi Fisika Kelompok Bidang Kajian Fisika Material

Disusun Oleh:

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**PROGRAM STUDI FISIKA**

**FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM**

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(Skripsi ini merupakan bagian dari payung penelitian Prof. Dr. Lilik Hasanah, M.Si.)

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Diajukan untuk memenuhi sebagian syarat untuk memperoleh gelar Sarjana Sains pada Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

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# LEMBAR PENGESAHAN SKRIPSI

LEMBAR PENGESAHAN SKRIPSI

ADI GUNAWAN

Pengaruh Massa $CuCl_2$ yang Ditambahkan dalam Sintesis $Ti_3C_2$ Menggunakan Metode *Molten Salt-Shielded Synthesis* (MS3) Terhadap Karakteristik Material.

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# ABSTRAK

$Ti_3C_2$ merupakan salah satu material MXene, yaitu material dua dimensi (2D) yang memiliki konduktivitas listrik tinggi serta potensi aplikasi luas dalam berbagai bidang, seperti sensor, elektroda superkapasitor, dan pelindung elektromagnetik. Namun, tantangan terkait sintesis $Ti_3C_2$ yang aman dan ramah lingkungan tanpa menggunakan asam fluorida (HF) masih menjadi perhatian utama. Penelitian ini bertujuan untuk mensintesis $Ti_3C_2$ menggunakan metode *Molten Salt-Shielded Synthesis* (MS3) dengan variasi massa $CuCl_2$, serta mengevaluasi pengaruhnya terhadap struktur kristal, morfologi, dan konduktivitas listrik dari $Ti_3C_2$ yang dihasilkan. Metode MS3 dipilih karena menawarkan keunggulan berupa prosedur yang lebih aman, tanpa bahan korosif berbahaya, serta memungkinkan kontrol sintesis yang lebih baik dibandingkan metode konvensional. Karakterisasi dilakukan menggunakan *X-ray Diffraction* (XRD) untuk analisis struktur kristal, *Scanning Electron Microscopy* (SEM) untuk morfologi, *Fourier Transform Infrared Spectroscopy* (FTIR) untuk identifikasi gugus fungsi, serta uji konduktivitas listrik. Hasil XRD menunjukkan bahwa variasi massa 4,146 gram $CuCl_2$ menghasilkan $Ti_3C_2$ dengan kristalinitas tertinggi, ditandai oleh pergeseran puncak indeks Miller (002) dan hilangnya puncak aluminium. SEM menunjukkan morfologi berlapis menyerupai akordeon dengan ketebalan rata-rata 112,585 nm. Nilai konduktivitas tertinggi sebesar 278,08 S/cm diperoleh pada variasi massa $CuCl_2$ 4,146 gram dengan lama 1 hari penyimpanan. Uji stabilitas menunjukkan bahwa konduktivitas menurun seiring waktu akibat oksidasi. Secara keseluruhan, metode MS3 dengan variasi massa $CuCl_2$ terbukti efektif menghasilkan $Ti_3C_2$ dengan struktur dan konduktivitas yang unggul, sekaligus menawarkan pendekatan sintesis yang lebih aman, efisien, dan berkelanjutan dibandingkan metode berbasis HF.



**Kata Kunci :** $Ti_3C_2$, MS3, $CuCl_2$, Sintesis, Karakterisasi

## ABSTRACT

$Ti_3C_2$ is one of the MXene materials, a two-dimensional (2D) material that has high electrical conductivity and wide application potential in various fields, such as sensors, supercapacitor electrodes, and electromagnetic shielding. However, challenges related to the safe and environmentally friendly synthesis of $Ti_3C_2$ without using hydrofluoric acid (HF) are still a major concern. This study aims to synthesize $Ti_3C_2$ using the Molten Salt-Shielded Synthesis (MS3) method with variations in $CuCl_2$ mass, and evaluate its effect on the crystal structure, morphology, and electrical conductivity of the resulting $Ti_3C_2$. The MS3 method was chosen because it offers the advantages of a safer procedure, without harmful corrosive materials, and allows better control of the synthesis compared to conventional methods. Characterization was performed using X-ray Diffraction (XRD) for crystal structure analysis, Scanning Electron Microscopy (SEM) for morphology, Fourier Transform Infrared Spectroscopy (FTIR) for functional group identification, and electrical conductivity test. XRD results show that the mass variation of 4.146 grams of $CuCl_2$ produces $Ti_3C_2$ with the highest crystallinity, characterized by a shift in the Miller index peak (002) and the disappearance of the aluminum peak. SEM shows an accordion-like layered morphology with an average thickness of 112.585 nm. The highest conductivity value of 278.08 S/cm was obtained in the $CuCl_2$ mass variation of 4.146 grams with a duration of 1 day of storage. The stability test showed that the conductivity decreased over time due to oxidation. Overall, the MS3 method with $CuCl_2$ mass variation proved effective in producing $Ti_3C_2$ with superior structure and conductivity, while offering a safer, more efficient, and sustainable synthesis approach compared to HF-based methods.



**Keywords:** $Ti_3C_2$, MS3, CuCl2, Synthesis, Characterization.

**DAFTAR ISI**

**DAFTAR GAMBAR**

## DAFTAR TABEL

## DAFTAR LAMPIRAN

## DAFTAR PUSTAKA

Abid, M. Z., Rafiq, K., Aslam, A., Jin, R., & Hussain, E. (2024). Scope, evaluation and current perspectives of MXene synthesis strategies for state of the art applications. Dalam *Journal of Materials Chemistry A*. Royal Society of Chemistry. https://doi.org/10.1039/d3ta06548k

Ahda, S., & Mahyudin, danAlimin. (2013). APLIKASI METODE MOLTEN SALT UNTUK SINTESIS BAHAN PIEZOELEKTRIK Bi 0,5 (Na 0,75 K 0,25 ) 0,5 TiO 3. *Jurnal Sains Materi Indonesia Indonesian Journal of Materials Science*, *14*(4), 284–289.

Bouderbala, I. Y., Herbadji, A., Mentar, L., & Azizi, A. (2018). Optical, structural, and photoelectrochemical properties of nanostructured Cl-doped Cu2O via electrochemical deposition. *Solid State Sciences*, *83*. https://doi.org/10.1016/j.solidstatesciences.2018.07.015

Chen, J., Jin, Q., Li, Y., Shao, H., Liu, P., Liu, Y., Taberna, P. L., Huang, Q., Lin, Z., & Simon, P. (2023). Molten Salt-Shielded Synthesis (MS3) of MXenes in Air. *Energy and Environmental Materials*, *6*(2). https://doi.org/10.1002/eem2.12328

Constant, S., Basset, C., Dumas, C., Di Renzo, F., Robitzer, M., Barakat, A., & Quignard, F. (2015). Reactive organosolv lignin extraction from wheat straw: Influence of Lewis acid catalysts on structural and chemical properties of lignins. *Industrial Crops and Products*, *65*. https://doi.org/10.1016/j.indcrop.2014.12.009

Dash, A., Vaßen, R., Guillon, O., & Gonzalez-Julian, J. (2019). Molten salt shielded synthesis of oxidation prone materials in air. Dalam *Nature Materials* (Vol. 18, Nomor 5, hlm. 465–470). Nature Publishing Group. https://doi.org/10.1038/s41563-019-0328-1

Feng, L., Lv, M., Qian, Q., Luo, R., & Huang, B. (2023). The synthesis of high purity Ti3AlC2 MAX phase via molten salt method. *Advanced Powder Technology*, *34*(1). https://doi.org/10.1016/j.apt.2022.103920

Ferroelectrics - Material Aspects. (2012). Dalam *Ferroelectrics - Material Aspects*. https://doi.org/10.5772/702

Garg, R., Agarwal, A., & Agarwal, M. (2020). A Review on MXene for energy storage application: Effect of interlayer distance. Dalam *Materials Research Express* (Vol. 7, Nomor 2). Institute of Physics Publishing. https://doi.org/10.1088/2053-1591/ab750d

Gautam, R., Marriwala, N., & Devi, R. (2023). A review: Study of Mxene and graphene together. *Measurement: Sensors*, *25*. https://doi.org/10.1016/j.measen.2022.100592

Ghidiu, M., Naguib, M., Shi, C., Mashtalir, O., Pan, L. M., Zhang, B., Yang, J., Gogotsi, Y., Billinge, S. J. L., & Barsoum, M. W. (2014). Synthesis and characterization of two-dimensional Nb4C3 (MXene). *Chemical Communications*, *50*(67), 9517–9520. https://doi.org/10.1039/c4cc03366c

Guo, T., Zhou, D., Deng, S., Jafarpour, M., Avaro, J., Neels, A., Heier, J., & Zhang, C. (2023). Rational Design of Ti3C2Tx MXene Inks for Conductive, Transparent Films. *ACS Nano*, *17*(4), 3737–3749. https://doi.org/10.1021/acsnano.2c11180

Hantanasirisakul, K., & Gogotsi, Y. (2018). Electronic and Optical Properties of 2D Transition Metal Carbides and Nitrides (MXenes). Dalam *Advanced Materials* (Vol. 30, Nomor 52). Wiley-VCH Verlag. https://doi.org/10.1002/adma.201804779

Hart, J. L., Hantanasirisakul, K., Lang, A. C., Anasori, B., Pinto, D., Pivak, Y., van Omme, J. T., May, S. J., Gogotsi, Y., & Taheri, M. L. (2019). Control of MXenes' electronic properties through termination and intercalation. *Nature Communications*, *10*(1). https://doi.org/10.1038/s41467-018-08169-8

Hu, W., Yang, M., Fan, T., Li, Z., Wang, Y., Li, H., Zhu, G., Li, J., Jin, H., & Yu, L. (2023). A simple, efficient, fluorine-free synthesis method of MXene/Ti3C2Tx anode through molten salt etching for sodium-ion batteries. *Battery Energy*, *2*(5). https://doi.org/10.1002/bte2.20230021

Huang, Z., Farahmandjou, M., Marlton, F., Guo, X., Gao, H., Sun, B., & Wang, G. (2024). Surface and structure engineering of MXenes for rechargeable batteries beyond lithium. Dalam *Journal of Materiomics* (Vol. 10, Nomor 1). https://doi.org/10.1016/j.jmat.2023.10.001

Idumah, C. I. (2023). Influence of morphology and architecture on properties and applications of MXene polymeric nanocomposites. Dalam *Journal of Thermoplastic Composite Materials* (Vol. 36, Nomor 10, hlm. 4124–4161). SAGE Publications Ltd. https://doi.org/10.1177/08927057221122096

Jia, L., Zhou, S., Ahmed, A., Yang, Z., Liu, S., Wang, H., Li, F., Zhang, M., Zhang, Y., & Sun, L. (2023). Tuning MXene electrical conductivity towards multifunctionality. Dalam *Chemical Engineering Journal* (Vol. 475). Elsevier B.V. https://doi.org/10.1016/j.cej.2023.146361

Jiang, T., Zou, T., Wang, G., Wang, B., & Chen, Z. (2022). Preparation and application study in a novel solar PV/thermal system of indium tin oxide nanofluid optical filter. *Energy Reports*, *8*. https://doi.org/10.1016/j.egyr.2022.04.026

Kaliyaraj Selva Kumar, A., Zhang, Y., Li, D., & Compton, R. G. (2020). A mini-review: How reliable is the drop casting technique? Dalam *Electrochemistry Communications* (Vol. 121). Elsevier Inc. https://doi.org/10.1016/j.elecom.2020.106867

Khan, R., & Andreescu, S. (2020). Mxenes-based bioanalytical sensors: Design, characterization, and applications. Dalam *Sensors (Switzerland)* (Vol. 20, Nomor 18, hlm. 1–19). MDPI AG. https://doi.org/10.3390/s20185434

Khanal, R., & Irle, S. (2023). Effect of surface functional groups on MXene conductivity. *Journal of Chemical Physics*, *158*(19). https://doi.org/10.1063/5.0141589

Koh, S. W., Rekhi, L., Arramel, N., Birowosuto, M. D., Trinh, Q. T., Ge, J., Yu, W., Wee, A. T. S., Choksi, T. S., & Li, H. (2023). Tuning the Work Function of MXene via Surface Functionalization. Dalam *ACS Applied Materials and Interfaces*. https://doi.org/10.1021/acsami.3c11857

Kumar, A., Shkir, M., Somaily, H. H., Singh, K. L., Choudhary, B. C., & Tripathi, S. K. (2022). A simple, low-cost modified drop-casting method to develop high-quality CH3NH3PbI3 perovskite thin films. *Physica B: Condensed Matter*, *630*. https://doi.org/10.1016/j.physb.2022.413678

Kumar, J. A., Prakash, P., Krithiga, T., Amarnath, D. J., Premkumar, J., Rajamohan, N., Vasseghian, Y., Saravanan, P., & Rajasimman, M. (2022). Methods of synthesis, characteristics, and environmental applications of MXene: A comprehensive review. *Chemosphere*, *286*. https://doi.org/10.1016/j.chemosphere.2021.131607

Kvashina, T. S., Uvarov, N. F., Korchagin, M. A., Krutskiy, Y. L., & Ukhina, A. V. (2020). Synthesis of MXene Ti3C2 by selective etching of MAX-phase Ti3AlC2. *Materials Today: Proceedings*, *31*, 592–594. https://doi.org/10.1016/j.matpr.2020.07.107

Lee, B. H., Park, S. H., Back, H., & Lee, K. (2011). Novel film-casting method for high-performance flexible polymer electrodes. *Advanced Functional Materials*, *21*(3). https://doi.org/10.1002/adfm.201000589

Li, Y., Shao, H., Lin, Z., Lu, J., Å Persson, P. O., Eklund, P., Hultman, L., Li, M., Chen, K., Zha, X.-H., Du, S., Rozier, P., Chai, Z., Raymundo-Piñero, E., Taberna, P.-L., Simon, P., & Huang, Q. (t.t.-a). *A general Lewis acidic etching route for preparing MXenes with enhanced electrochemical performance in non-aqueous electrolyte*.

Li, Y., Shao, H., Lin, Z., Lu, J., Å Persson, P. O., Eklund, P., Hultman, L., Li, M., Chen, K., Zha, X.-H., Du, S., Rozier, P., Chai, Z., Raymundo-Piñero, E., Taberna, P.-L., Simon, P., & Huang, Q. (t.t.-b). *A general Lewis acidic etching route for preparing MXenes with enhanced electrochemical performance in non-aqueous electrolyte*.

Li, Y., Shao, H., Lin, Z., Lu, J., Å Persson, P. O., Eklund, P., Hultman, L., Li, M., Chen, K., Zha, X.-H., Du, S., Rozier, P., Chai, Z., Raymundo-Piñero, E., Taberna, P.-L., Simon, P., & Huang, Q. (t.t.-c). *A general Lewis acidic etching route for preparing MXenes with enhanced electrochemical performance in non-aqueous electrolyte*.

Li, Z., Wang, L., Sun, D., Zhang, Y., Liu, B., Hu, Q., & Zhou, A. (2015). Synthesis and thermal stability of two-dimensional carbide MXene Ti3C2. *Materials Science and Engineering: B*, *191*(C), 33–40. https://doi.org/10.1016/j.mseb.2014.10.009

Liang, C., He, J., Cao, Y., Liu, G., Zhang, C., Qi, Z., Fu, C., & Hu, Y. (2023). Advances in the application of Mxene nanoparticles in wound healing. Dalam *Journal of Biological Engineering* (Vol. 17, Nomor 1). BioMed Central Ltd. https://doi.org/10.1186/s13036-023-00355-7

Liu, L., Orbay, M., Luo, S., Duluard, S., Shao, H., Harmel, J., Rozier, P., Taberna, P. L., & Simon, P. (2022). Exfoliation and Delamination of Ti3C2TxMXene Prepared via Molten Salt Etching Route. *ACS Nano*, *16*(1), 111–118. https://doi.org/10.1021/acsnano.1c08498

Liu, L., Raymundo-Piñero, E., Taberna, P. L., & Simon, P. (2023). Electrochemical characterization of Ti3C2Tx MXene prepared via a molten salt etching route in an acetonitrile-based electrolyte. *Electrochemistry Communications*, *148*. https://doi.org/10.1016/j.elecom.2023.107453

Liu, Z., Xu, J., Xi, X., Luo, W., & Zhou, J. (2023). Molten salt dynamic sealing synthesis of MAX phases (Ti3AlC2, Ti3SiC2 et al.) powder in air. *Ceramics International*, *49*(1), 168–178. https://doi.org/10.1016/j.ceramint.2022.08.325

Ma, C., Ma, M. G., Si, C., Ji, X. X., & Wan, P. (2021). Flexible MXene-Based Composites for Wearable Devices. Dalam *Advanced Functional Materials* (Vol. 31, Nomor 22). John Wiley and Sons Inc. https://doi.org/10.1002/adfm.202009524

Maleski, K., Ren, C. E., Zhao, M. Q., Anasori, B., & Gogotsi, Y. (2018). Size-Dependent Physical and Electrochemical Properties of Two-Dimensional MXene Flakes. *ACS Applied Materials and Interfaces*, *10*(29), 24491–24498. https://doi.org/10.1021/acsami.8b04662

Nezami, S., Ghaemi, A., & Yousefi, T. (2024). Experimental exploring of Ti3C2Tx MXene for efficient and deep removal of magnesium in water sample. *Scientific reports*, *14*(1), 27508. https://doi.org/10.1038/s41598-024-78942-x

Parker, T., Zhang, D., Bugallo, D., Shevchuk, K., Downes, M., Valurouthu, G., Inman, A., Chacon, B., Zhang, T., Shuck, C. E., Hu, Y. J., & Gogotsi, Y. (2024). Fourier-Transform Infrared Spectral Library of MXenes. *Chemistry of Materials*. https://doi.org/10.1021/acs.chemmater.4c01536

Persson, P. O. Å., & Rosen, J. (2019). Current state of the art on tailoring the MXene composition, structure, and surface chemistry. *Current Opinion in Solid State and Materials Science*, *23*(6). https://doi.org/10.1016/j.cossms.2019.100774

Qdemat, A., Kentzinger, E., Buitenhuis, J., Rücker, U., Ganeva, M., & Brückel, T. (2020). Self assembled monolayer of silica nanoparticles with improved order by drop casting. *RSC Advances*, *10*(31), 18339–18347. https://doi.org/10.1039/d0ra00936a

Riazi, H., Anayee, M., Hantanasirisakul, K., Shamsabadi, A. A., Anasori, B., Gogotsi, Y., & Soroush, M. (2020). Surface Modification of a MXene by an Aminosilane Coupling Agent. *Advanced Materials Interfaces*, *7*(6). https://doi.org/10.1002/admi.201902008

Sadidi, M., Hajilary, N., & Abbasi, F. (2023). Fabrication of a new composite membrane consisting of MXene/PES /PEI for biofuel dehydration via pervaporation. *Results in Engineering*, *18*. https://doi.org/10.1016/j.rineng.2023.101071

Sarycheva, A., & Gogotsi, Y. (2020). Raman Spectroscopy Analysis of the Structure and Surface Chemistry of Ti3C2T xMXene. *Chemistry of Materials*, *32*(8), 3480–3488. https://doi.org/10.1021/acs.chemmater.0c00359

Sezen, S., Zarepour, A., Zarrabi, A., & Iravani, S. (2023). MXene-based biosensors for selective detection of pathogenic viruses and bacteria. Dalam *Microchemical Journal* (Vol. 193). https://doi.org/10.1016/j.microc.2023.109258

Shuck, C. E., Sarycheva, A., Anayee, M., Levitt, A., Zhu, Y., Uzun, S., Balitskiy, V., Zahorodna, V., Gogotsi, O., & Gogotsi, Y. (2020). Scalable Synthesis of Ti3C2Tx MXene. *Advanced Engineering Materials*, *22*(3). https://doi.org/10.1002/adem.201901241

Siringo-Ringo, M. (t.t.). *Kebijakan Energi dan Dampak Lingkungan: Menuju Model Berkelanjutan*.

Sohan, A., Banoth, P., Aleksandrova, M., Nirmala Grace, A., & Kollu, P. (2021). Review on MXene synthesis, properties, and recent research exploring electrode architecture for supercapacitor applications. Dalam *International Journal of Energy Research* (Vol. 45, Nomor 14, hlm. 19746–19771). John Wiley and Sons Ltd. https://doi.org/10.1002/er.7068

Thakur, A., Chandran B.S., N., Davidson, K., Bedford, A., Fang, H., Im, Y., Kanduri, V., Wyatt, B. C., Nemani, S. K., Poliukhova, V., Kumar, R., Fakhraai, Z., & Anasori, B. (2023). Step-by-Step Guide for Synthesis and Delamination of Ti3C2Tx MXene. *Small Methods*, *7*(8). https://doi.org/10.1002/smtd.202300030

Vaia, R. A., Jawaid, A., Hassan, A., Neher, G., Nepal, D., Pachter, R., Joshua Kennedy, W., & Ramakrishnan, S. (2021). Halogen etch of Ti3AlC2 MAX phase for mxene fabrication. *ACS Nano*, *15*(2). https://doi.org/10.1021/acsnano.0c08630

Wang, J., Li, G., Xie, G., Huang, Z., Zhang, P., Xu, B., Xie, X., & Zhang, N. (2024a). Solvation structure design for stabilizing MXene in transition metal ion solutions. *SusMat*, *4*(3). https://doi.org/10.1002/sus2.202

Wang, J., Li, G., Xie, G., Huang, Z., Zhang, P., Xu, B., Xie, X., & Zhang, N. (2024b). Solvation structure design for stabilizing MXene in transition metal ion solutions. *SusMat*, *4*(3). https://doi.org/10.1002/sus2.202

Wang, J., Yan, M., Zhu, Y., Huang, J., Chen, H., Deng, Y., Chen, Y., & Albina, J.-M. (t.t.). *Etching Mechanism of Ti 3 C 2 Cl 2 MXene Phases by CuCl 2-Lewis Molten Salt Method*. https://ssrn.com/abstract=4700854

Wang, Y., Xu, Y., Hu, M., Ling, H., & Zhu, X. (2020). MXenes: Focus on optical and electronic properties and corresponding applications. Dalam *Nanophotonics* (Vol. 9, Nomor 7, hlm. 1601–1620). De Gruyter. https://doi.org/10.1515/nanoph-2019-0556

Wu, L., Lu, X., Dhanjai, Wu, Z. S., Dong, Y., Wang, X., Zheng, S., & Chen, J. (2018). 2D transition metal carbide MXene as a robust biosensing platform for enzyme immobilization and ultrasensitive detection of phenol. *Biosensors and Bioelectronics*, *107*, 69–75. https://doi.org/10.1016/j.bios.2018.02.021

Yan, M., Zhu, Y., Huang, J., Chen, H., Deng, Y., Chen, Y., Wang, J., & Albina, J. M. (2024). Etching Mechanism of Ti3C2Cl2 MXene Phases by CuCl2-Lewis Molten Salt Method. *Journal Wuhan University of Technology, Materials Science Edition*, *39*(4), 863–868. https://doi.org/10.1007/s11595-024-2947-x

Yang, L. X., Wang, Y., Zhang, H. L., Liu, H. J., & Zeng, C. L. (2019). A simple method for the synthesis of nanosized ti3alc2 powder in nacl-kcl molten salt. *Materials Research Letters*, *7*(9), 361–367. https://doi.org/10.1080/21663831.2019.1613695

Yoon, J., Shin, M., Lim, J., Lee, J. Y., & Choi, J. W. (2020). Recent Advances in MXene Nanocomposite-Based Biosensors. Dalam *Biosensors* (Vol. 10, Nomor 11). https://doi.org/10.3390/BIOS10110185

Zhou, Z., Liu, J., Zhang, X., Tian, D., Zhan, Z., & Lu, C. (2019). Ultrathin MXene/Calcium Alginate Aerogel Film for High-Performance Electromagnetic Interference Shielding. *Advanced Materials Interfaces*, *6*(6). https://doi.org/10.1002/admi.201802040