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Plasmas for additive manufacturing

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Abstract - Low-temperature plasmas have played a vital role in materials manufacturing such as the fabrication of semiconductor-based electronics. Plasmas are typically used to etch and deposit thin films *subtractively*, in which undesired areas of a larger material are removed to produce the desired pattern or shape. Recently, *additive* methods to materials manufacturing have emerged that create structures with minimal wasteage by building up a structure layer-by-layer. With the ability to process materials at low temperature, carry out non-equilibrium chemistry, and conform to three-dimensional shapes, plasmas offer enticing possibilities for additive manufacturing, much like the contributions that have already been made in subtractive manufacturing.[1] In this talk, I will present an overview of recent progress towards applying plasmas in additive strategies to materials synthesis in my group as well as others. In particular, two general strategies will be present. One, through electrode confinement, microscale plasmas can locally modify films to directly write patterns.[2,3,4] Two, plasmas can be combined with printing methods to treat or convert deposited precursors.[5,6,7,8] Current challenges and a future outlook for plasmas in additive manufacturing will also be discussed.

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3. S. Ghosh, E. Ostrowski, R. Yang, D. Debnath, P. X-L., Feng, C. A. Zorman, and R. M. Sankaran, "Atmospheric-pressure plasma reduction of metal cation-containing polymer films to produce electrically conductive nanocomposites by an electrodiffusion mechanism," *Plasma Chem. Plasma Proc.* **36**, 295-307 (2016).
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6. T. Liu, K. Premasiri, Y. Sui, X. Zhan, H. Mustafa, O. Akkus, C. Zorman, X. Gao, and R. M. Sankaran, "Direct, transfer-free growth of large-area hexagonal boron nitride films by plasma-enhanced chemical film conversion (PECFC) of printable, solution-processed ammonia borane," *ACS Appl. Mater. Inter.* **10**, 43936-43935 (2018).
7. Y. Sui, Y. Dai, C. C. Liu, R. M. Sankaran, and C. A. Zorman, "A new class of low-temperature plasma-activated, inorganic salt-based particle-free inks for inkjet printing metals," *Adv. Mater. Technol.* **4**, 1900119 (2019).
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Short Bio

R. Mohan Sankaran is the Donald Biggar Willett Professor in Engineering at the University of Illinois at Urbana-Champaign (UIUC). He received his B.S. in Chemical Engineering from the University of California Los Angeles in 1998 and his Ph.D. in Chemical Engineering from the California Institute of Technology. He began his independent academic career in the Department of Chemical and Biomolecular Engineering at Case Western Reserve University as an Assistant Professor in 2005, was promoted to Associate Professor in 2010, then promoted to Professor in 2014. In 2020, he moved to the Department of Nuclear, Plasma, and Radiological Engineering at UIUC. His research program focuses on developing atmospheric-pressure plasmas as a chemical platform for the synthesis of novel materials and small molecules with applications in emerging electronics, medicine, and energy conversion. He has co-authored over 100 peer-reviewed journal articles, edited one book, and contributed several book chapters. He has been recognized for his research achievements by the Camille and Henry Dreyfus Teacher-Scholar Award and the AVS Peter Mark Memorial Award. He currently serves as an Associate Editor of the *Journal of Vacuum Science and Technology* and a member of the Editorial Board of *Plasma Chemistry Plasma Processing*, *Scientific Reports*, and *Plasma Research Express* and the Advisory Board of the *Journal of Physics D*.