Disruptive metal oxide nanocrystals by atmospheric pressure microplasmas

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Transition metal oxides (TMOs) are an extraordinary class of materials that have found wide applicability for a number of century-defining technologies (e.g. flat-panel display, capacitors and energy storage) mainly due to their dielectric properties and chemical inertness. Doping, defect engineering, quantum confinement and extending to clusters, ternary or high entropy oxides can create disruptive materials with new or improved properties. Atmospheric pressure microplasmas represent a viable synthesis platform to achieve exceptional tuning capability therefore achieving an exquisite control of the size, composition and defects of TMO nanoparticles [1-3]. Microplasmas offer dial-up delivery of precursor radicals together with tunable temperature conditions for nanoparticle formation, followed by rapid quenching [4]. These microplasma conditions can lead to unprecedented crystal structures that can be constructed in a bottom-up approach [5-7]. In this contribution we will show how quantum confinement and extensive defects in metal oxide nanoparticles can produce very desirable opto-electronic properties. Therefore we will discuss the formation of TMO nanoparticles with gas-phase microplasmas as well as hybrid plasma-liquid systems [8, 9]. The pros and cons of these microplasma synthesis approaches will be revealed and opportunities explored also in terms of manufacturing scalability and process integration [10, 11]. We will further provide in-depth analysis of the TMO nanoparticles, including their application opportunities in energy conversion and storage [12-14]. Examples will include oxides from Ni, Cu, Mn, Sn, Co, Mo and Zn [15, 16]. Finally we will provide future directions at the boundaries between ordered and disordered crystal structures.

References

[1] Chiang W-H *et al.* Adv Mater 32 (2020), 1905508
[2] Wagner A J *et al.* Physical Review E 80 (2009) 065401R
[3] Abuyazid N *et al.* Plasma Sources Science & Technology 29 (2020) 075011
[4] Haq AU *et al.* Plasma Processes and Polymers 17 (2020) 1900243
[5] Haq AU *et al.* Nature Communications 10 (2019) 817
[6] Askari S *et al.* Nanoscale 8 (2016) 17141
[7] Ghosh S *et al.* Journal of Physics D: Applied Physics 48 (2015) 314003
[8] Velusamy T *et al.* Plasma Processes & Polymers 14 (2017) 1600224
[9] Padmanaban DB *et al.* Green Chemistry 23 (2021) 3983
[10] Brunet P *et al.* Nanoscale Advances 3 (2021) 781
[11] Liu Y *et al.* Scientific Reports 5 (2015) 15765
[12] McGlynn R *et al.* Solar Energy 203 (2020) 37
[13] Chakrabarti S *et al.* Nanoscale Advances 1 (2019) 4915
[14] Alessi B *et al.* Faraday Discussions 222 (2020) 390
[15] Ni C *et al.* Crystal Growth & Design 19 (2019) 5249
[16] Ni C *et al.* Green Chemistry 20 (2018) 2101

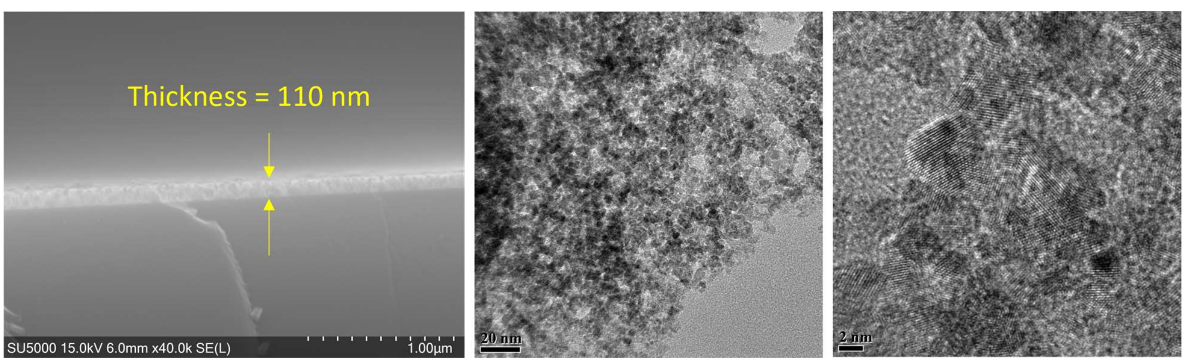

Figure 1. (a) Cross sectional image of a NiO nanoparticle thin film deposited with a gas-phase atmospheric pressure microplasma for application in solar energy conversion. (b-c) corresponding transmission electron microscope images showing the nanoparticle structure of the film and crystalline nature.