

Low-temperature strategies to induce the crystallization of metal oxide thin films by wet chemical methods

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The versatility of wet chemical methods facilitates the exploration of novel crystallization pathways for metal oxide thin films and makes them fundamental in the development of low-temperature strategies for the preparation of advanced inorganic materials. The benefits obtained from decreasing the processing temperature (and hence the energy consumption) of the fabrication process span from minimizing the environmental impact to reducing the manufacturing cost of the product. More challenging is however the preparation of complex oxide layers at temperatures compatible with their direct integration into flexible systems using polymeric substrates (≤ 350 °C). The high crystallization temperatures of the former materials (500-700 °C) usually impede the development of electronic devices that take full advantage of the large variety of oxide functionalities available (electrical, magnetic and optical). Here, we present a number of strategies based on wet chemical methods for inducing the crystallization of metal oxide thin films at low temperatures.^[1] The key mechanisms of these approaches are explained in relation to the specific step of the fabrication process that is promoted: the formation of a defect-free, highly densified amorphous metal–oxygen network or the actual crystallization of the metal oxide. Thus, low-temperature strategies such as (i) molecular design, (ii) heterogeneous photocatalysis, (iii) electronic photoactivation, (iv) combustion synthesis, or (v) seeding effect are particularly highlighted. Relevant examples derived from the direct growth of different oxide layers (BiFeO_3 , $\text{Pb}(\text{Zr,Ti})\text{O}_3$ or Bi_2O_3) on flexible polymeric substrates showing multiple functionalities (ferroelectricity, piezoelectricity, magnetism, photovoltaic effect or photocatalytic activity) will illustrate the most recent achievements reached in this field by our group.^[2]

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[1] Bretos et al., *Chem. Eur. J.* 26, 2020, 9277; Bretos et al., *Chem. Soc. Rev.* 47, 2018, 291.

[2] Barrios et al., *Adv. Funct. Mater.* 2022; Bretos et al., *Adv. Funct. Mater.* 30, 2020, 2001897; Tomczyk et al., *J. Mater. Chem. C* 5, 2017, 12529; Pérez-Mezcua et al., *Sci. Rep.* 6, 2016, 39561; Bretos et al., *Adv. Mater.* 27, 2015, 2608; Bretos et al., *Adv. Mater.* 26, 2014, 1405.