Critical Materials and PV cells interconnection

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Given the exponential growth of deployed photovoltaic (PV) energy sources, we have to question how to make such growth sustainable. Transition at global scale from fossil fuels to mineral-based renewable energies will indeed induce a sharp turn in materials supply chains. The concept of critical materials covers various sources of supply tensions. More precisely in PV sector, concerns grow for the last few years about Silver price volatility, relative to its scarcity, or about Indium related to its availability.

Raw material criticity definition is open to question. No consensus seems to arise yet from literature in order to define influencing factors on criticity. For this study, five supply hazard criteria are selected in order to represent accurately each material supply situation: geological, logistical, geopolitical, industrial and commercial. With those criteria, the materials (and their substitutes) used in PV modules interconnection are listed and for each one, criticity is assessed. List of those elements is the following: Aluminum, Bismuth, Copper, Indium, Nickel, Silver and Tin.

Although different dynamics may be observed depending on the concerned material, the main conclusion is that, except Aluminum, all listed elements supplies should face supply tensions by 2050, or even 2030 for the most critical ones [1]. It is important to note that for most of these materials, PV sector has not triggered its critical status.

Two material groups should be distinguished. In the first hand, high production and consumption volumes materials (Aluminum and Copper) should not restrict PV energy production capacity expansion projections in the short term but could adversely affect growth in the mid term: by 2050, Copper demand to electrify the whole society should deplete global reserves so its supply is unreliable; it is then compulsory to deeply rethink energy networks, as well as implement a circular approach (reduce, repair, reuse and finally recycle). Moreover, aluminum needed volume for PV on TW scale would induce huge CO_2 emissions [2]. On the other hand, other materials (Bismuth, Indium, Silver, and Tin) are used in PV interconnection in dispersive ways: even though PV sector requires a limited amount, they are difficult to recover. These applications must evolve otherwise the known reserves will end around 2040.

It draws one main conclusion in the specific case of PV sector: conception has to evolve from dispersive cells interconnection processes, such as low temperature soldering or conductive adhesive bonding. In general, conception step has to focus on end-of-life step to introduce more circular methodologies. Change may happen at three levels: process, material or architecture. Changing or optimizing the deposition process is largely covered in literature over the last 15 years and Silver consumption reduction potential seems to reach its limit [3]. Alternative materials have been rising for the last 5 years and could have a great impact on metallization criticity. In the meantime, critical materials consumption in interconnection could further shrink with a disruptive innovation in module architecture. A few innovation examples, from NICE concept to non-uniform metallization, will be presented.

[1] Valero, Alicia et al. « Material Bottlenecks in the Future Development of Green Technologies ». Renewable and Sustainable Energy Reviews 93 (2018): 178-200.

[2] Lennon, Alison et al. « The Aluminum Demand Risk of Terawatt Photovoltaics for Net Zero Emissions by 2050 ». Preprint. In Review, 2021.

[3] « ITRPV 2021 ». VDMA, March 2022.