I+D+i EN CIENCIA Y TECNOLOGÍA DE MATERIALES

THIN FILMS PUBLICATION TRENDS

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Abstract

This article analyses the worldwide scientific publications trends related to thin films for the last 5 years with a special focus in Spain and Portugal (the Iberian Peninsula region). We studied the evolution of the different thin films topics published. We then confirmed, following our previous study published in 2018, that during this four last year the same tendency for the Iberian Peninsula persist: one of the most published topic in thin films is related to solar cells. We have entered in more details in the publication trends related to solar cells.

Keywords: Thin Films, Statistic analysis, Solar cells.

1. INTRODUCTION.

It has been a long time since thin films came to the attention of the scientific community, but the research on this topic has not stopped, increasing since then. Therefore, companies such as Photon Export have the need and obligation not to be left behind and to keep up to date in order to provide the scientific community with the finest types of equipment and consumables that best fit their interests and goals.

Photon Export is a global provider of sputtering targets, up to $5N^i$ pure evaporation materials for PVD and all types of substrates from specialty glass to single crystals wafers. In Spain and Portugal, Photon Export supplies thin films and semiconductor process equipment for both research and industry purposes.

A thin film is a single or multiple layers of a material that does not exceed in thickness a few micrometres. There are several methods to produce thin films, such as Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD), growth or Atomic Layer Deposition. All of these methods have in common that the material is deposited or grown over a substrate/wafer at high vacuum conditions.

This report intends to analyse the trends of the research on the topic of thin films, both worldwide and in the Iberian Peninsula. The methodology used consists on the analysis of the indexed keywords, the titles and abstracts of all literature published by the most renowned scientific journals on the topics of materials science, physics and engineering through the Elsevier academic research database Scopus. A special attention and complex logic operations ensure that single article which includes several topics is not counted more than once. For example: the topic "solar cells" includes the study of semiconductivity applied to solar cells, while the topic semiconductors, includes all those articles which studied semiconductivity not focusing on the solar cells applications.

2. WORLDWIDE TRENDS.

More than 530.000 articles are available under the topic of "thin films" in the Scopus database. We have started the evolution analysis since 1995. As a continuity of our previous trend analysis we have focus on those published between 2018 and 2021.

Figure 1 shows all main thin films categories topics publish between 2018 and 2021 worldwide.

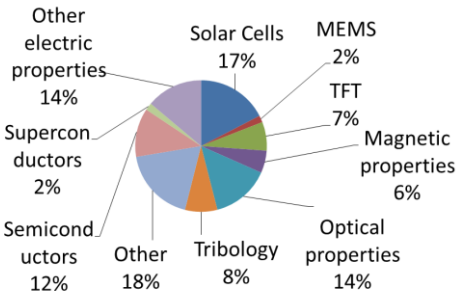

Figure 1 Percentages of the main topics covered by the analysed articles, where MEMS stands for Micro Electro Mechanical Systems and TFT for Thin Film Transistors.

The electrical properties of thin films, elevated conductivity and low resistivity are, for the moment, the subjects that generate more interest among the scientific community, in particular in solar cells applications.

It has not always been this case, as shown in Figure 2, showing that the research focusing on optical properties, in particular on lens coatings, was the most published until 2011. For the last 15 years, research focused on optical properties has remained constant. On the other hand, research on solar cells escalated rapidly from 2007 and became the most published topic outplacing optical properties. For the last few years, it seems that research has not changed its direction. Solar cell remains the most published topic but the number of published articles related to semiconductivity has also shown a fast increase.

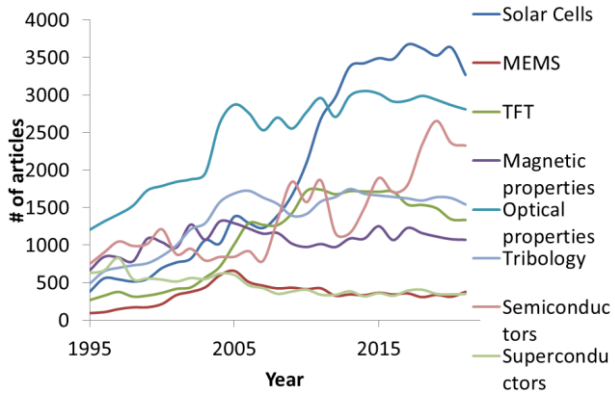

Figure 2. Number of articles published of each topic for the last 25 years.

Solar cells have stayed the most published topic for the last 10 years. There is a significant need for alternative energy sources to replace fossil fuels, and efficient and economic ways of producing green energy are a top priority to reverse climate change. Since 2012 research on perovskite solar cells has been increasing nonstop until 2021 when it has decreased around a 5%, as shown in Figure 3. In opposition, publications on silicon solar cells have been decreasing for the last 10 years. Zinc compounds solar cells, such as CZTS, have also been decreasing during the last 10 years, but at a much lower rate.

The state of research at the moment is shown in Figure 4, being perovskite solar cell over a 30% of total solar cells literature and more than twice zinc compounds, being the second solar cell materials topic most published.

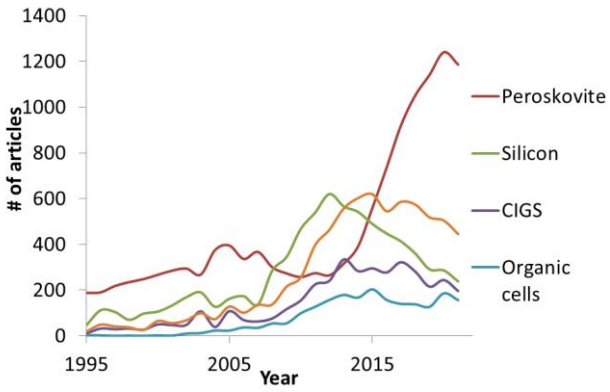

Figure 3 Evolution of the solar cell literature according to the different types of solar cells studied.

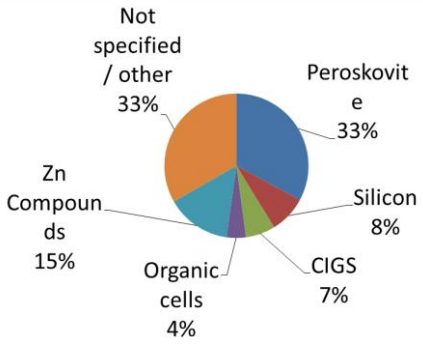

Figure 4. Classification of the solar cell literature according to the different types of solar cells studied.

3. SPAIN AND PORTUGAL TRENDS.

The production of scientific literature in Spain and Portugal is notably lower than in other countries, being the 13th and 33rd in the top publishing countries regarding thin films respectively. The number of articles published represents a 2.4% of the total amount. Nevertheless, the main research lines remain remarkably similar to the worldwide trend, as it is shown in Figure 5.

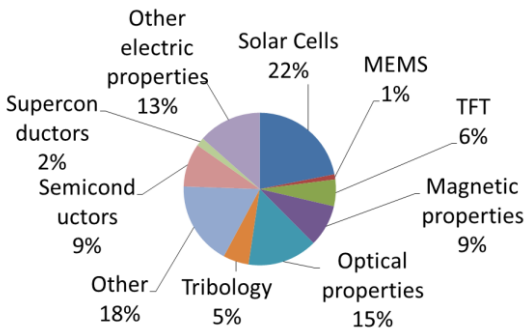

Figure 5 Percentages of the main topics covered published by the Spanish and Portuguese's scientific communities.

3.1. Iberian R&D speciality: Solar Cells.

Spain and Portugal Solar Cells publications reach a 22% of the total thin films literature, 5% more than the worldwide trend, while the remaining topics stay within very similar percentages. Time evolution does not show significant changes either.

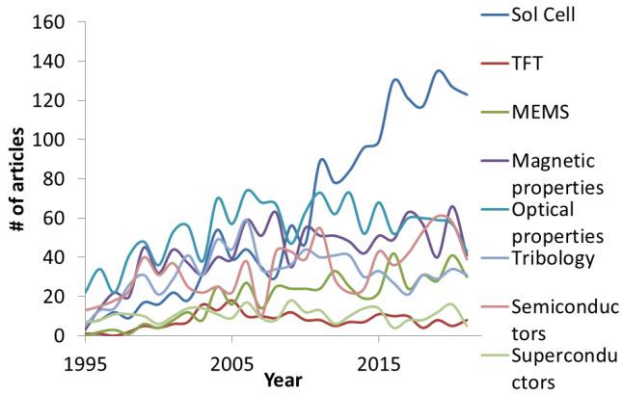

Figure 6 Number of articles published by each subject in Spain and Portugal during the last 25 years.

When focusing on solar cells publications it must be taken into account that the number of articles analysed is much lower, many restrictions have been applied by now; therefore, lower variations in terms of absolute numbers may be shown as major variations in terms of relative parameters. Figure 7 shows that CIGS solar cells research represent a larger proportion than it does globally, around 11%, while perovskite and Zn solar cells literature maintain similar percentages to those in Figure 4. The CIGS solar cells are made by copper indium gallium selenide thin films.

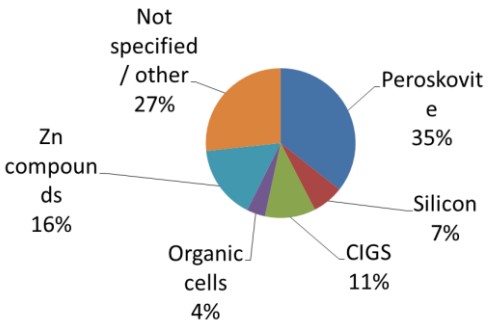

Figure 7 Classification of the literature published on the solar cells subject in Spain and Portugal.

In Figure 8 it is shown that the number of publications on perovskite and CIGS thin film solar cells has grown over the past decade, with a number of articles published of more than three times higher for both of them since 2011. On the other hand, although zinc-related publications had increased rapidly until 2017, they have started a moderate decrease, which goes down to a 50% during the last 4 years.

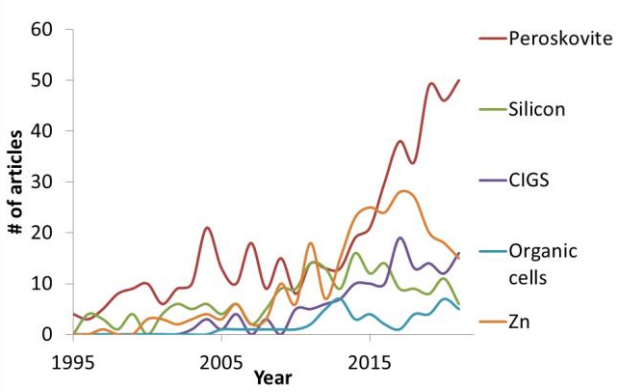

Figure 8 Evolution of the solar cell literature according to the different types of solar cells studied in Spain and Portugal.

4. SOLAR CELLS.

Perovskite thin film solar cells have dominated the quantity of publications on solar cells for the last ten years. Due to the huge energetic and economic cost of the ultra-pure silicon wafers production, alternative materials were on the need to make photovoltaic cells a feasible replacement to oil derivatives. But what is perovskite? It is a crystalline compound with chemical formula ABX_3, where A is a cation, X a halide anion and B a Pb^{2+} ion. Perovskite solar cell has achieved at the moment 25.7% efficiency (reported by the U.S. National Renewable Energy Laboratory (NREL)[ii]). Perovskite thin films manufacturing is a simpler process and requires much less energy than silicon solar cells. [1],[2]

The publishing rate of the other types of solar cells is in slow recession as shown in Figure 3. Nevertheless CZTS and CIGS solar cells still represent a 27% of the publications related to solar cells. The maximum efficiency registered by a CIGS solar cell is 23.4% according to the NRL.

Diversification of solar cells materials is the key to achieve larger efficiencies. A single-junction solar cell is limited to a theoretical efficiency index of 32 to 35% (Shockley–Queisser limit) due to the low range of wave lengths that are capable of absorb. On the other hand, multi-junction solar cells are predicted to be able to achieve 85% of efficiency. This type of solar cells combines various semiconductors so that different wave lengths can be absorbed at the same time. With this method, up to a 47.1% of efficiency index has been achieved according to the NREL with concentrated solar light. Its downsides, their elevated cost make them, for now, not suitable for mass production and terrestrial applications, although their use in the space industry is habitual [3].

5. CONCLUSIONS.

After our first publication 4 years ago, we have polished our methodology, enlarging the time scope analysing trends since 1995 and focusing this last period. We have not seen any radical change on trends and the tendencies remain similar: Solar cells still stands as the major researched subject, with similar percentages[iii] over the total number of articles published, around 17%. Perovskite solar cells publications represent over a 30% of the solar cell literature both worldwide and in the Iberian Peninsula, other thin film technologies such as CIGS solar cells shows a second position reaching 11% of the solar cells publications. Progress in the cost-effectiveness viability of solar cells will inevitably go thorough multi-junction solar cells, by combining different semiconductors such as perovskite, CIGS, CZTS and the, by now, well-known silica.

6. REFERENCES.

[1] A. K. Jena, A. Kulkarni, and T. Miyasaka, Halide perovskite photovoltaics: Background, status, and future prospects, Chemical reviews 119, 3036 (2019).

[2] Perovskite solar cell (2020), https://www.cei.washington.edu/education/science-of-solar/perovskite-solar-cell/, last checked 19/07/2022.

[3] M. Yamaguchi, F. Dimroth, J. F. Geisz, N. J. Ekins-Daukes, Multi-junction solar cells paving the way for super high-efficiency, Journal of Applied Physics 129, 240901 (2021), https://doi.org/10.1063/5.0048653.

[4] M. Gaitan and E. Barrera, Thin films scientific state of the art trends, Material-ES 2 (2018).

[i] *99.999% purity.*

[ii] *https://www.nrel.gov/pv/assets/pdfs/best-research-cell-efficiencies-rev220630.pdf*

[iii] *to the percentages published in [3].*