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Perovskites: Endless Source of "Functionalities"

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The growing technological needs of the modern society require more demanding devices for applications in microelectronics, fuel cells, solar cells, sensors etc. For all these applications, high-performance materials with the necessary properties are needed in thin film forms, which have to be produced with high-throughput synthetic technologies such as the versatile and challenging metal-organic chemical vapor deposition (CVD) and atomic layer deposition.

Perovskites and the related ilmenite structures represent an amazing class of materials due to the huge variety of functional properties they may possess. The term perovskite was used for the first time in 1839 by Gustave Rose who named the mineral $CaTiO_3$, discovered in the Ural mountains, after Russian mineralogist L. A. Perovski. Later the term perovskite has been used to indicate compounds of general formula ABX_3, where A and B are cations of very different size, A being always larger than B, and X is the anion, typically oxygen or halogens. In particular, A is usually an alkaline, alkaline-earth or rare-earth metal, B is an alkaline-earth, rare-earth or transition metal.

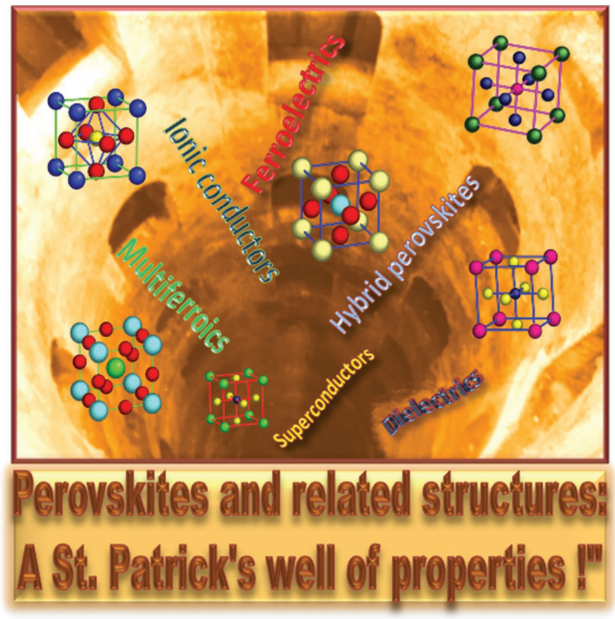

Figure 1. Perovskites, and related structures: A Saint Patrick's well of properties.

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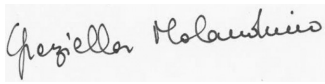

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But what make this class of compounds so stimulating and challenging? i) the possibility to use almost whatever metal from the periodic table for the A and B site, of course considering the coordination constraints, which imply a 12-fold cuboctahedral coordination for the A cation and a 6-fold octahedral coordination for the B cation; ii) the flexibility in doping this structure both at the A and B sites; iii) the cation dimensions, which play a pivotal role in determining the perovskite structure according to the invaluable classification of Prof. Victor Goldschmidt.[1] All these issues give rise to an enormous number of properties. For this reason, perovskites have been named "inorganic chameleons" by Prof. A. R. West,[2] but I prefer to consider perovskites as a *Saint Patrick's well of functionalities*, where we can pick up the properties we want by tailoring the perovskite composition.

Thus, if we include unpaired electron elements such as Mn, Co, Fe, etc., in the B site we produce magnetic materials, ferromagnetic or colossal magnetoresistive, while if we include atoms with lone pairs such Bi, Pb etc. we end up with ferroelectric systems. These are just two of the endless number of properties, which include superconductors, multiferroic, thermoelectric, thermochromic, giant-k, dielectric, proton conductors, mixed conductors, etc. All these properties make perovskites attractive not only for basic research in materials science, but also for applications in microelectronics, telecommunication, spintronics, fuel cells, and photovoltaics.

The interest in perovskites has further flourished after the seminal study reported in 2009 by the group of Prof. T. Miyasaka[3] on the potential of hybrid perovskites, e.g. $CH_3NH_3PbI_3$, in photovoltaics. The number of publications on

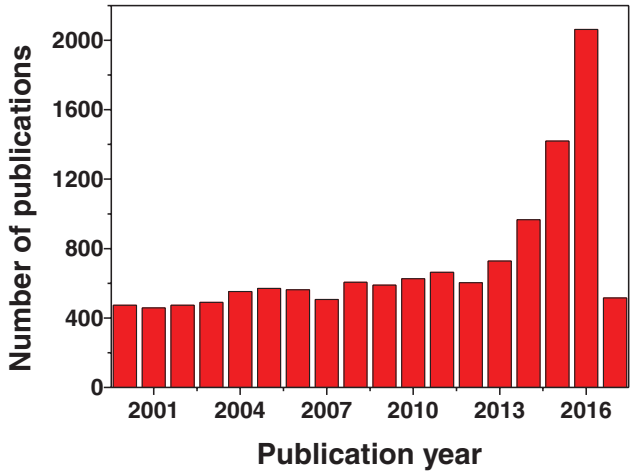

Figure 2. Number of publications with topics containing "perovskites".[4]

perovskites, which has usually covered some hundreds of publications per year until 2012, has grown astonishingly to thousands per year once the report outcomes of hybrid perovkites became effective in the photovoltaic scientific community. The number of publications per year, obtained from a search with the topic "perovskites" in the SciFinder database, is reported in the graph of **Figure 2**.

In this Special Issue Section, an invited collection of two Reviews and four Research News are included. One Review deals with the synthesis of the ilmenite structure epitaxial films of lithium niobate and lithium tantalate, which possess exceptional acoustic, electro-optical, pyroelectric and ferroelectric properties. The second Review gives an overview of the application of the challenging atomic layer deposition technology to synthesize ferro-magnetic, piezo- and ferro-electric perovskite and ilmenite films. The four Research News cover other appealing functionalities of perovskites: dielectric, multiferroic, ionic conduction and specific properties for photovoltaics. Specifically, one Research News addresses the dielectric properties of the $CaCuTi_3O_4$ films in correlation to the substrate nature, the second Research News discusses the engineering of functional manganite films for miniaturized fuel cell devices, while the third one focuses on the effect of the doping ions on the structural and functional properties of $BiFeO_3$ films. The fourth Research News summarizes the recent progress of hybrid perovskites grown by CVD approaches.

Finally, as guest editor of this Special Issue Section, I would like to sincerely acknowledge all the authors for their interesting and valuable contributions.

[1] V. M. Goldschmidt, *Naturwissenschaften*, **1926**, *14*, 477.
[2] A. R. West, *Solid state chemistry and its applications*, second edition, John Wiley & Sons, Hoboken, USA, **2014**.
[3] A. Kojima, K. Teshima, Y. Shirai, T. Miyasaka, *J. Am. Chem. Soc.*, **2009**, *131*, 6050.
[4] March **2017**. https://scifinder.cas.org/scifinder/