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A brief overview of Materials Science in Uruguay

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ABSTRACT

Materials science is a growing research area in Uruguay. In order to obtain a brief overview of the research done we collected information about research in this field. As a starting point, we searched in the Scopus database for the keywords: affiliation country: "Uruguay" and subject: "Materials Science" (using the "Timbó" platform). We inspected the records and we analyzed them to construct a timeline. The data show that we are in a steady state regime of number of publications that we expect to increase together with the number of students in the

area, with the generation of long term policies (grants, funding opportunities), and, if we get involved in a community that promotes this area of interest.

INTRODUCTION

Uruguay has just above 3.5 million inhabitants and it is located in South America between two bigger countries, Argentina and Brazil. Regarding scientific publications, there is a big gap among Latin American countries. A possible explanation for this difference is how much each country has invested in science. The number of published articles has grown in recent years in Latin America. However, the number should be even higher considering gross domestic product. Among all Latin American countries, Brazil leads the list followed by Argentina.

Materials science is under-represented in Uruguay. Evidence of this is the lack of a Degree in Material Science Engineering. Only in the year 2000, a 5-year Degree in Material Chemistry was installed at "Facultad de Química" (Chemistry School) of Universidad de la República (Udelar). In spite of this, a small community of researchers have been working in materials science in Uruguay over the years (Physicists, Chemical Engineers, Chemists, etc.), and the number of students that pursue a career in materials science is on the rise.

Due to the lack of specific data about materials science history in our country, during the organization of an inaugural conference of young researchers in the spring of 2018 held in Montevideo, Uruguay, we asked ourselves how Uruguay is positioned in terms of material science research. We decided to collect information about research in this field.

The present work aims to present a brief overview of the materials science field in Uruguay in order to promote future national policies regarding materials science.

As a starting point, we have searched in the Scopus database for the keywords: affiliation country: "Uruguay" and subject: "Materials Science" (using the "Timbó" platform [1]). At the time of writing this article (April 2018), we found more than 720 records comprising conference papers and journal articles. This work does not take into account patents, since we focus on academic research. In order to validate the number of articles and proceedings records, we took into account only the papers that appeared in the SCIMAGO database [2]. After applying this refinement procedure to our search we were left with a total of 549 hits. Further analysis will be presented in the result and discussion section.

It should be mentioned that, from our point of view, not all the articles related to material science developed in Uruguay are indexed in the Scopus database in the subject "material science". In any case, the sample is still representative.

According to Scopus database, if we consider the total number of publications made by researchers based in Uruguay, there are 20.617 articles. When we considered those articles related to Material Science, without any further constraints or verification, we obtained 720 results (representing 3.5 % of the total number of publications). Using the same procedure to search in Argentina and Brazil, we found that 7.3 % and 7.1 % are articles related to materials science, respectively. Considering the difference in population reported by the United Nations (43.85 million Argentina and 207.9 million Brazil), it is obvious that Uruguay presents a comparable lower number of publications in the area of Material Science than our neighbor countries.

Figure 1 shows the number of publications of Uruguayan research over the last 45 years. A clear increase is observed, mainly after 1995. On the other hand, Uruguay, like other Latin American countries, has suffered turbulent periods in which national policies were compromised [3]. During dictatorship (1973-1985), the number of

publications was kept almost constant at a very low rate. It is worth acknowledging the great effort that has been made in the latest period, (from 2007 onwards), when the Innovation and Research National Agency (Agencia Nacional de Investigación e Innovación, ANII), was created.

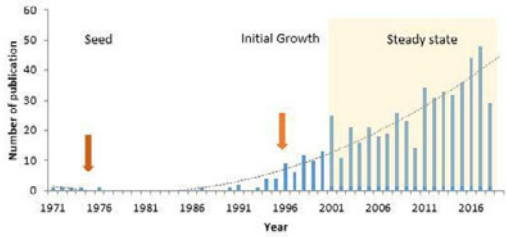

Figure 1- Number of publications related to materials science based in Uruguay between 1973-2018 (source Scopus).

The majority of the works were carried out at the "Universidad de la República" - Udelar in its different Schools ("Facultad de Ingeniería", School of Engineering (FI), "Facultad de Ciencias", School of Science, (FC), "Facultad de Química", School of Chemistry, (FQ)). Some works were carried out under the name of state companies such as "Administración Nacional de Cementos, Alcoholes y Portland" (ANCAP), "Administración Nacional de Usinas y Transmisiones Eléctricas" (UTE) and there is a minority of them carried out by private institutions (most of which have been recently created).

The first period of the plot in figure 1 (between 1971 – 1978, the "seed phase"), can be considered the cornerstone of the development of the materials science field in Uruguay. This work was developed principally by Saravia and Casamayou, at the "Instituto de Física" (Physics Institute) from the FI and was focused on calculations of the photoelectric effect in germanium [4], optical properties in CdTe [5], photoemission of GaAs [6], and later piezo-optical properties of silicon [7].

In previous years there were advances, mostly in the field of Chemistry and Physics, as well as in the development of some instrumental techniques at UDELAR [8]–[17]. Some examples are the works by Maggiolo De Gerszonowicz et al. [8] in the instrumental area developed in FI, as well as the subsequent work by Hirschfeld et al. [12], [13] in the FQ. On the other hand, there are works in the analytical area carried on by Frugoni [9] and Dittrich [14] in the FQ, as well as those by Burastero et al. [10], [16] in the former scientific research division of ANCAP. Additionally, we can also mention inorganic chemistry works by Giglio [11], Michaelis De Saenz et al. [17] and Píriz MacColl [15] carried out in FQ.

At that time, incipient studies in heterogeneous catalysis developed by Nieto [18] in the FQ can also be mentioned, as well as studies of mechanical properties of conducting-polymer in Panizza et al's work [19], materials and spin-lattice relaxation of $SnCl_2$ properties by Mognaschi et al. [20] developed in FI. In the eighties, works adjacent to the area of materials in theoretical chemistry made by Ventura in the FQ can be found [21].

Following these works, the results in the Scopus database show that the second series of works that ended up creating, promoting, and consolidating the area of materials science in Uruguay ("the growing phase"), were in the field of inorganic chemistry and for radiopharmaceutical applications by Kremer et al. [22], on theoretical models of

electrical properties in thermistors by Slomovitz et al. [23,24], on preparation and characterization of fine films of metal alloys by Bonilla et al. [25], and on the preparation and characterization of superconducting ceramics by Veretnik and A.W.Mombrú et al. [26]. We could also include into these series, the work done by Baran et al [27] in the field of metallic complexes. On the other hand, there are also studies on heterogeneous catalysis by Bussi et al. [28] and others on pillared clays by Diano et al. [29], and on catalytic behavior of lanthana by Castiglioni [30] as well as studies on structural defects in copper crystals by Moreno-Gobbi et al. [31]. Furthermore, we can list works done on the inhibition of Ni corrosion performed by Zinola et al. [32]. In the same decade we can also list the works on studies of semiconductor electrical properties developed by Masoller et al. [33], as well as works on piezoelectricity in ceramics and composite materials developed by Alles et al. [34] and Negreira et al. [35] respectively.

Towards the end of the nineties, works on biopolymers by Miraballes et al. [36] can be found, on rhenium complexes [37] as well as works on the preparation and study of optical-electrical properties on mercuric iodide developed by Fornaro et al. [38]. Also, works on superconducting ceramics by Pardo et al. [39] as a continuation of the research line initiated by Mombrú. At the beginning of the 21st century the work on the growth of porous silicon films by Marotti et al. appears [40] as a continuation of Dalchiele's, on theoretical chemistry by Denis et al. [41] as a continuation of Ventura's work, and on new coordination compounds by Chiozzone et al. [42] as a continuation of Kremer's work.

After the year 2000 (considered by us as the "steady state phase"), works on stability studies physical chemistry of surfaces ranging from colloidal by Odriozola et al. [43], surface reactivity of electrodes by Méndez et al. [44], as well as activated carbon adsorption properties of Tancredi et al. [45] can be found. Works on semiconductors done by Saucedo [46] and Cuña [47] as a continuation of Fornaro's work were published. Some years later, new corrosion studies were published by Ohanian et al. [48] as a continuation of Zinola's work, on elastic and magnetic superconducting properties by Stari et al. [49] and Suescun et al. [50], respectively, both as a continuation of the works by Moreno and Mombrú, respectively. We can also mention some works on coordination compounds with various applications developed by Torre et al. [51] and Cerdá et al. [52], in the latter case as a continuation of the work initiated by Kremer. In the same year, articles can be found on mechanical properties and materials with applications in the biomedical area by Armentano et al. and Sánchez et al. [53], as well as in the construction materials area by Rodríguez De Sensale [54]. In addition, in these years works in the study of ferroelectric materials by Aulet et al. [55] can be found as a continuation of the work by Negreira.

By the end of the first decade of the 21st century there are papers by Faccio et al. [56], Sarasúa et al. [57] working with magnetic properties, Noguera et al. working with nucleation in HgI_2 [58], Muñoz et al. working on thin films [59]. At the same time, Mombrú et al. [60,56] published experimental and theoretical studies on ferromagnetism in nanostructured graphite.

As of today, the specific scientific production of the area of materials science with authors or co-authors of Uruguayan affiliation totals approximately 550 documents. The most recurrent topics in the area of materials science in Uruguay are subdivided into: type of materials, preparation techniques, instrumental techniques and computational tools. By type of materials, the most common are nanoparticles and nanostructures, thin films and ceramic materials. The most usual preparation techniques are typically chemical or physical deposition; in particular electrodeposition, chemical synthesis, especially sol-gel and formation of complexes in aqueous solution. The most frequently used instrumental techniques are X-ray diffraction, scanning and transmission electron microscopy including high resolution, study of electrochemical and optical properties, as

well as vibrational spectroscopy, atomic force microscopy and X-ray photoelectron spectroscopy. The most frequently used computational techniques are density functional theory (DFT) and, to a lesser extent, simulations using molecular dynamics (MD).

Considering the tendency of the research, it is expected that during the year 2030, 200 more papers will be published.

FINAL REMARKS

From the brief overview of the results found in Scopus database and with the constraints imposed to the data, we found materials science publications that were relevant in their context since the beginning of this field in Uruguay. Also, we can say that we are in a steady state regime of number of publications which are expected to increase together with the number of students in the area, with the generation of long term policies (grants, funding opportunities) and if we get involved in a community that promotes this area of interest.

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