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THE IMPACT OF BULK NANOSTRUCTURED MATERIALS IN MODERN RESEARCH

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Abstract. An analysis was conducted to evaluate the impact of the broad field of severe plastic deformation, ultrafine-grained materials and nanostructured materials on modern Materials Science. Although this research area was first introduced only two decades ago, citation data are used for major journals in Materials Science to demonstrate that the field has had a remarkable impact. Specifically, the all-time two most-cited articles in the major review journal are from this area and more than one-half of the top ten all-time most cited papers are from this area for the four major research journals.

1. INTRODUCTION

The processing of high-strength metals through the application of severe plastic deformation (SPD) has a long history dating back more than two thousand years to the artisans of ancient China and extending through the production of Wootz steel in India and Damascus steel in the Middle East [1]. The first comprehensive scientific approach may be traced to the extensive work on the effect of high pressures on metals conducted about 70 years ago by Nobel Laureate Professor P.W. Bridgman at Harvard University. Bridgman was the first to propose the basic principles of the high-pressure torsion (HPT) technique [2] and later, in the former Soviet Union at Sverdlovsk (now Yekaterinburg), this was further developed into a viable processing procedure [3]. At approximately the same time, the basic principles of equal-channel angular pressing (ECAP) were developed in Minsk [4]. Nevertheless, despite the extensive attention given to SPD processing methods, these procedures remained relatively unknown until the classic work of Valiev and co-workers in Ufa demonstrating that metals processed by SPD have ultrafine-grained microstructures and, furthermore, they have the capability of exhibiting attractive properties such as extensive superplastic flow at elevated temperatures [5]. It is apparent from this brief summary that the processing of ultrafine-grained metals by SPD has a relatively short history extending over only about 20 years. Thus, this field is very new by comparison

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Table 1. The five journals selected for detailed analysis.

Name of journal	*Impact factor*	*Total numbers of papers*
Progress in Materials Science	18.132	313
Acta Materialia	3.729	7028
Scripta Materialia	2.887	7187
Materials Science and Engineering A	1.806	19165
Metallurgical and Materials Transactions A	1.389	5363

with the long-established and more traditional research fields in materials science.

Despite this short history, there has been a very considerable impact from SPD research and the processing of nanostructured metals in the modern materials science literature. Large numbers of papers appear regularly, from research laboratories around the world, describing new experimental results and analytical data from research conducted in the processing of metals by ECAP, HPT and other similar SPD techniques. These many publications suggest that the field of ultrafine-grained and nanostructured metals has probably produced a major impact in materials science in terms of the numbers of citations recorded by the major publications in the field. The present paper, which was given orally at the Bulk Nanostructured Materials conference (BNM-2009) in Ufa during the week of September 21-26, 2009, represents an attempt to quantify the impact of this field in modern materials science.

All of the data contained within this report were taken from the Web of Science produced by ISI (The Institute for Scientific Information, Philadelphia, PA) and available as a subscription-only website. Since the numbers on this website are updated on a daily basis, it should be noted that the numbers documented in this report are already out of date. Thus, the present numbers were collected over the weekend of September 12 and 13, 2009, and they provide essentially a snapshot of the situation immediately prior to the BNM-2009 meeting. The exact citation numbers will be a little higher at the time of publication of this paper and in addition there may be minor changes in the rankings of some of the papers. Nevertheless, the present report provides a valuable overview of the precise significance of this research area within the discipline of Materials Science.

2. THE IMPETUS FOR THIS ANALYSIS

The impetus for this analysis lies in a paper entitled "Producing Bulk Ultrafine-Grained Materials by Severe Plastic Deformation" prepared by the members of the International NanoSPD Steering Committee and published in JOM in 2006 [6]. This paper defined the basic terms in the field of SPD processing and it was cited sufficiently that, despite the fact that JOM is not a regular research journal, it was selected by ISI as their "hot paper" in Materials Science for July 2007 where this relates to the selection by ISI of a "hot paper" in each of several selected disciplines every two months. An analysis in September 2009 showed this paper was ranked as all-time #1 in JOM with 170 citations and, in addition, other papers in the SPD field were ranked, based on the numbers of citations, as #2 with 55 citations [7] and #5 with 38 citations [8].

These results led to the question of the overall impact of the SPD and nanostructured materials field in materials science. The following section describes an analysis undertaken to determine this impact.

3. AN ANALYSIS OF MAJOR JOURNALS IN MATERIALS SCIENCE

Five different journals were selected for detailed analysis and these are shown in Table 1 where the first column gives the journal name, the second column gives the Impact Factor and the third column shows the total numbers of papers published in each journal up to the date of the analysis in mid-September 2009. It should be noted that *Progress in Materials Science* publishes lengthy reviews on selected topics and therefore the numbers of published papers is low but the Impact Factor is very high. The remaining four journals are regular research journals and they represent the major journals containing papers on SPD processing and ultrafine-grained and nanostructured materials.

Table 2. Analysis for *Progress in Materials Science.*

Ranking	*Author(s)*	*Reference*	*Numbers of citations*
1	Gleiter	[9]	1976
2	Valiev, Islamgaliev and Alexandrov	[10]	1738

Table 3. Analysis for *Acta Materialia.*

Ranking	*Author(s)*	*Reference*	*Numbers of citations*
2	Gleiter	[11]	815
3	Iwahashi, Horita, Nemoto and Langdon	[12]	579
4	Iwahashi, Horita, Nemoto and Langdon	[13]	479
6	Kumar, Van Swygenhoven and Suresh	[14]	434
7	Saito, Utsunomiya, Tsuji and Sakai	[15]	420
9	Sanders, Eastman and Weertman	[16]	346

Table 4. Analysis for *Scripta Materialia*.

Ranking	*Author(s)*	*Reference*	*Numbers of citations*
1	Iwahashi, Wang, Horita, Nemoto and Langdon	[17]	710
2	Saito, Tsuji, Utsunomiya, Sakai and Hong	[18]	296
5	Mukai, Yamanoi, Watanabe and Higashi	[19]	229
7	Valiev, Salimonenko, Tsenev, Berbon and Langdon	[20]	198
9	Tsuji, Ito, Saito and Minamino	[21]	188

Table 5. Analysis for *Materials Science and Engineering A.*

Ranking	*Author(s)*	*Reference*	*Numbers of citations*
1	Segal	[22]	987
3	Valiev, Korznikov and Mulyukov	[23]	650
4	Valiev, Krasilnikov and Tsenev	[24]	532
5	Furukawa, Iwahashi, Horita, Nemoto and Langdon	[25]	464
8	Birringer	[26]	311
10	Herzer	[27]	274

Table 6. Analysis for *Metallurgical and Materials Transactions A.*

Ranking	*Author(s)*	*Reference*	*Numbers of citations*
3	Ferrasse, Segal, Hartwig and Goforth	[28]	201
5	Horita, Fujinami, Nemoto and Langdon	[29]	179
7	Iwahashi, Horita, Nemoto and Langdon	[30]	165
8	Iwahashi, Horita, Nemoto and Langdon	[31]	164
9	Oh-ishi, Horita, Furukawa, Nemoto and Langdon	[32]	162

For each journal, the Web of Science was used to determine the all-time ten most cited papers appearing in each publication and from this list the papers relevant to SPD processing and ultrafine-grained and nanostructured materials were retained and the other papers were discarded. Tables 2 to 6 summarize the results of this analysis for each separate journal.

In Table 2 for *Progress in Materials Science*, it is apparent there are only two papers related to SPD and the nanostructured field but these papers are ranked in the #1 and #2 positions and both have >1500 citations. For the remaining journals, the listing is extremely strong and includes the #1 papers in both *Scripta Materialia* and *Materials Science and Engineering A*.

4. SUMMARY AND CONCLUSIONS

The field embraced by SPD processing, ultrafine-grained materials and nanostructured materiuals has had a major impact on publications appearing over the last decade within the discipline of Materials Science. The present analysis of the top ten most-cited papers appearing in each of five major journals shows that this field represents the two most highly cited papers appearing in *Progress in Materials Science* which concentrates exclusively on lengthy review articles, six of the top ten most-cited papers in *Acta Materialia* and *Materials Science and Engineering A* and five of the top ten most-cited papers appearing in *Scripta Materialia* and *Metallurgical and Materials Transactions A*. This means that for the latter four major research journals the broad nanoSPD field has provided >50% of the all-time most cited papers. This is a remarkable achievement which provides a clear demonstration of the keen interest in this research area. A perusal of the other papers appearing in the top ten listings shows that topics such as metallic glasses and friction stir processing also receive large numbers of citations.

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