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Commentary

Global Research Trends in Thermal Sprayed Coatings Technology Analyzed with Bibliometrics Tools

Research Publications for Thermal Spray Technology Continue to Rise

Thermal spraying coating processes experienced strong growth in the 1990s and into the 21st century as new applications were found to benefit from coatings formed on a surface through high velocity impact of molten or semi-molten particles (Ref 1, 2). Among the thermal spray processes, plasma spray remains the most versatile. Other thermal spray processes, including flame spray (Ref 3, 4), high velocity oxy-fuel (HVOF) spraying (Ref 5, 6), and cold gas kinetic spraying (or cold spray) (Ref 7, 8), find important application niches. Thanks to its ease of implementation and the associated cost benefits, thermal spray coating technology continues to fit specific industrial application needs (Ref 9-17) and finds vast applications in aerospace technology (Ref 18), energy industry (Ref 3, 19), chemical engineering(Ref 3), construction (Ref 20), automobile (Ref 21), and agriculture. Research publication output and impact on thermal spray technology have also grown rapidly along with the technology growth.

This commentary provides a bibliometric analysis of research papers on thermal spray technology during the last 20 years (1995-2014), as extracted from Scopus and Web of Science databases, and analyzed to provide a basic understanding of the global research in this field. The number of annual scholarly outputs and their impact, mainstream journals in which they have been published, and leading countries and institutions from which the papers have originated have emerged from analyses of the publication data.

Annual Scholarly Output and Impact

Figure 1 provides the global annual number of publications related to various thermal spray coating technologies. Thermal spray or plasma spray dominates the number of publications while publications on cold spray have increased rapidly over the past 10 years (compound annual growth rate (CAGR*) of 20.1%).

*The CAGR is the mean annual growth rate of a measure (such as publications or citations) over a specific period of time (>1 year).

Figure 2 shows the field-weighted citation impact (FWCI**) for the publications on thermal spray published in each year, and Table 1 provides that for publications on thermal spray in different journal categories. One can find that the FWCI of publications published in recent years generally have a lower FWCI than those published in the past. In addition, publications dealing with energy, environmental science, and chemical engineering have the highest FWCI among all papers published in the field of thermal spray technologies.

Leading Countries and Institutions

Figure 3 and 4 present the top countries and institutions contributing to publications on thermal spray coating technology. The USA took a lead position among countries/territories, followed by Japan, China, Germany, and France during 1995 to 2004, whereas China led in thermal spray publications during 2005 to 2014. For institutions involved in thermal spray technology publications, SUNY Stony Brook and Nanyang Technological University (Singapore) were the two leading institutions during the period 1995 to 2004, while Xi'an Jiaotong University (PR China) and UTBM (France) became the leaders in the last 10 years (2005-2014).

Mapping of Leading Journals, Technical Terms, and Institutions

Figure 5 shows that *Surface & Coatings Technology, Journal of Thermal Spray Technology,* and *Materials Science and Engineering A* are the three most preferred journals for publishing thermal spray research. However, it can be seen in Fig. 5b that *Journal of Thermal Spray Technology* (JTST) is the dominant journal for peer reviewed articles in cold spray technology from 1990 to 2014.

Figure 6 shows the research area trends by mapping the technical terms used in the titles and abstracts in the publications in each 5-year period. Only terms that oc-

**The FWCI is the ratio of the total citations actually received by the denominator's output, and the total citations that would be expected based on the average of the subject field (as defined by Scopus, Elsevier). If an output is part of more than one subject field, the expected citations in each field are determined, and the harmonic average is used as the input into Field-Weighted Citation Impact.

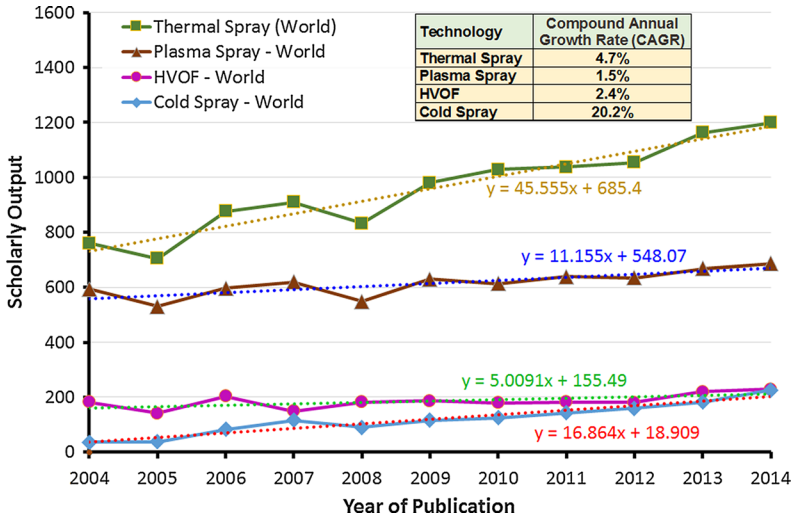


Fig. 1 Global scholarly output searched by different spray technology as keywords in Elsevier SciVal

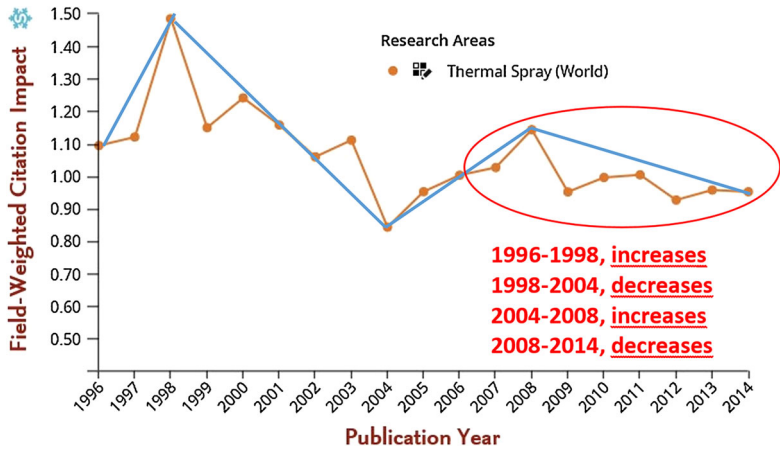
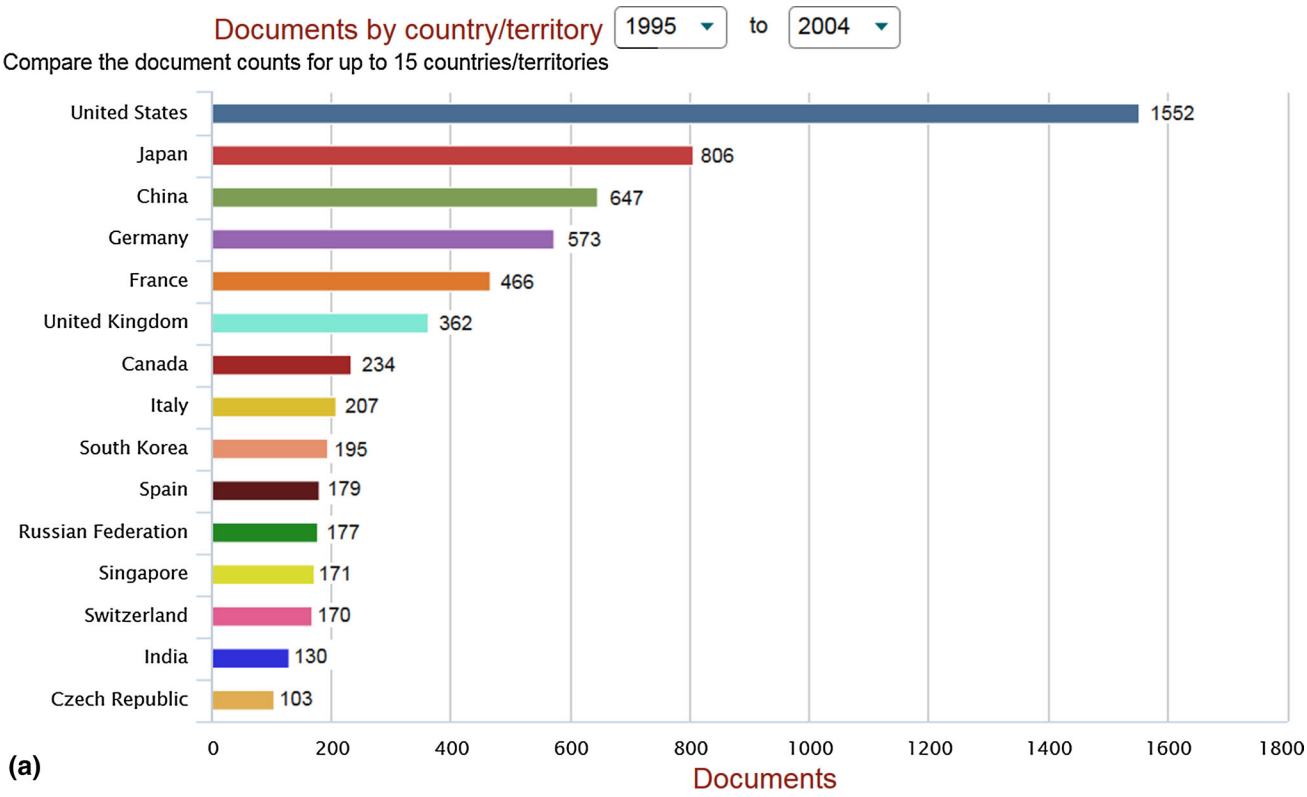


Fig. 2 FWCI of thermal spray publications over the years

Table 1 Field-weighted citation impact (FWCI) for thermal spray technology publications by journal category (Elsevier)

Publications by Journal Category — 2010 to 2014

Journal Category	Publications	Citations	Field-Weighted Citation Impact
Worldwide (all)	11,265	41,931	0.96
Materials Science	5,951	23,761	0.90
Engineering	4,828	11,737	0.94
Physics and Astronomy	4,112	16,798	0.97
Chemistry	2,133	13,839	1.03
Chemical Engineering	1,318	8,171	1.26
Energy	908	5,151	1.52
Environmental Science	528	2,200	1.39



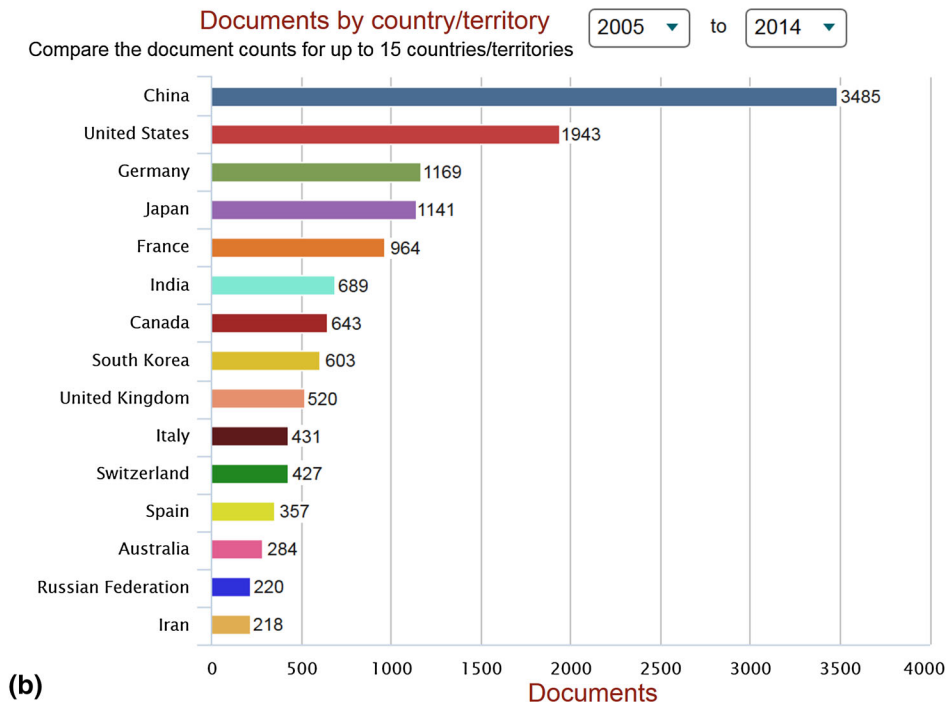
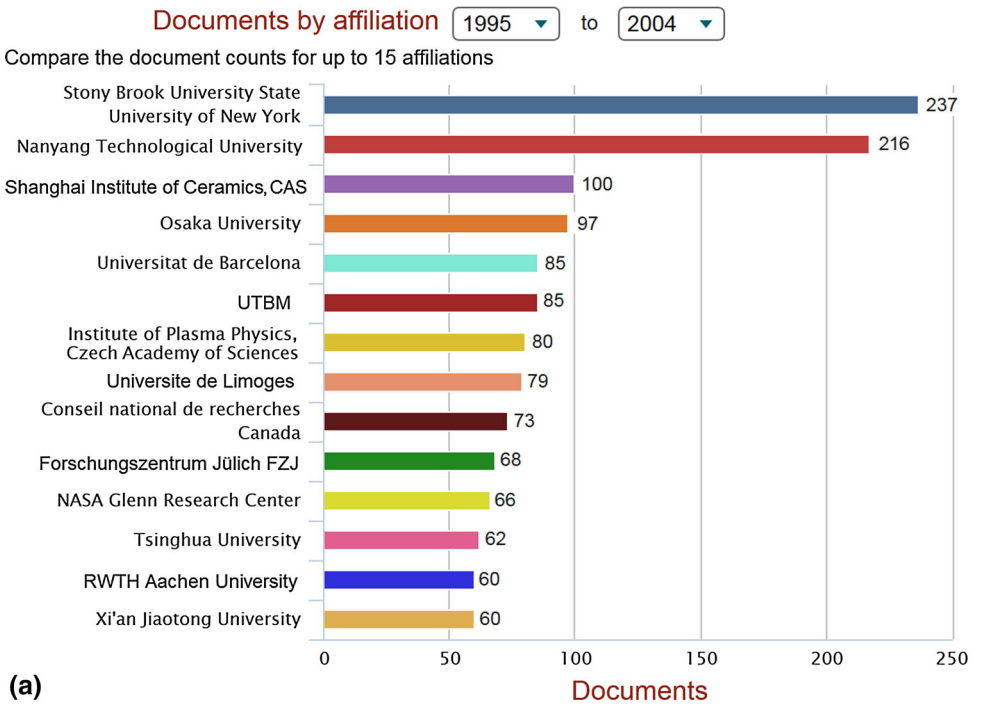


Fig. 3 Top countries contributing to publications on thermal spray technologies. (a) 1995-2004. (b) 2005-2014



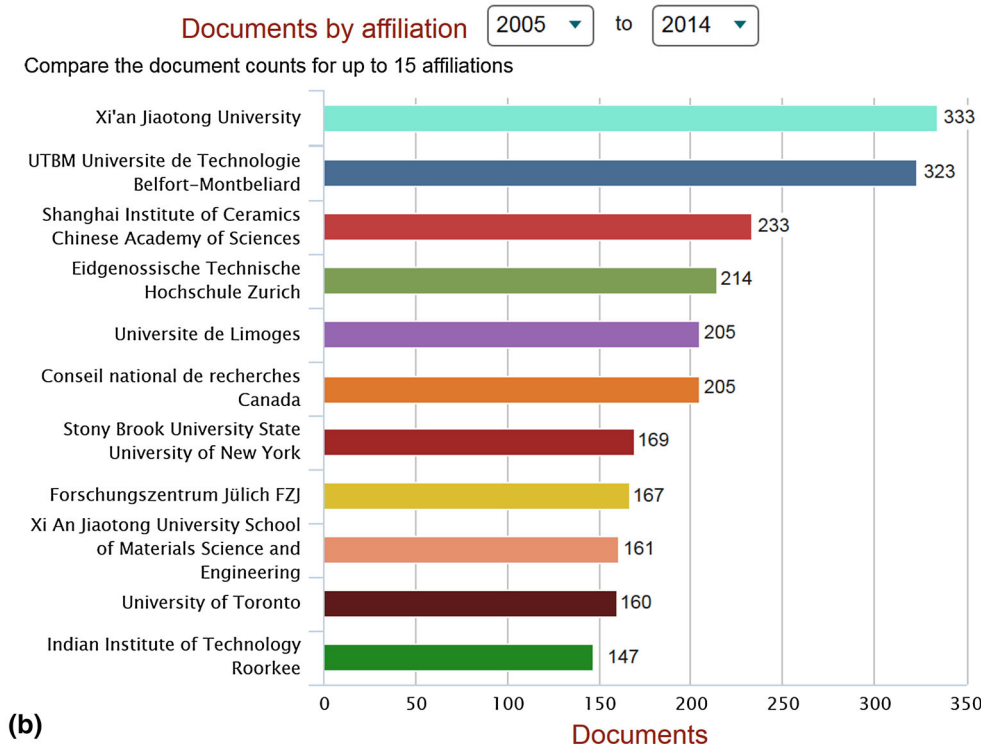


Fig. 4 Top institutions contributing to publications on thermal spray technologies. (a) 1995-2004. (b) 2005-2014

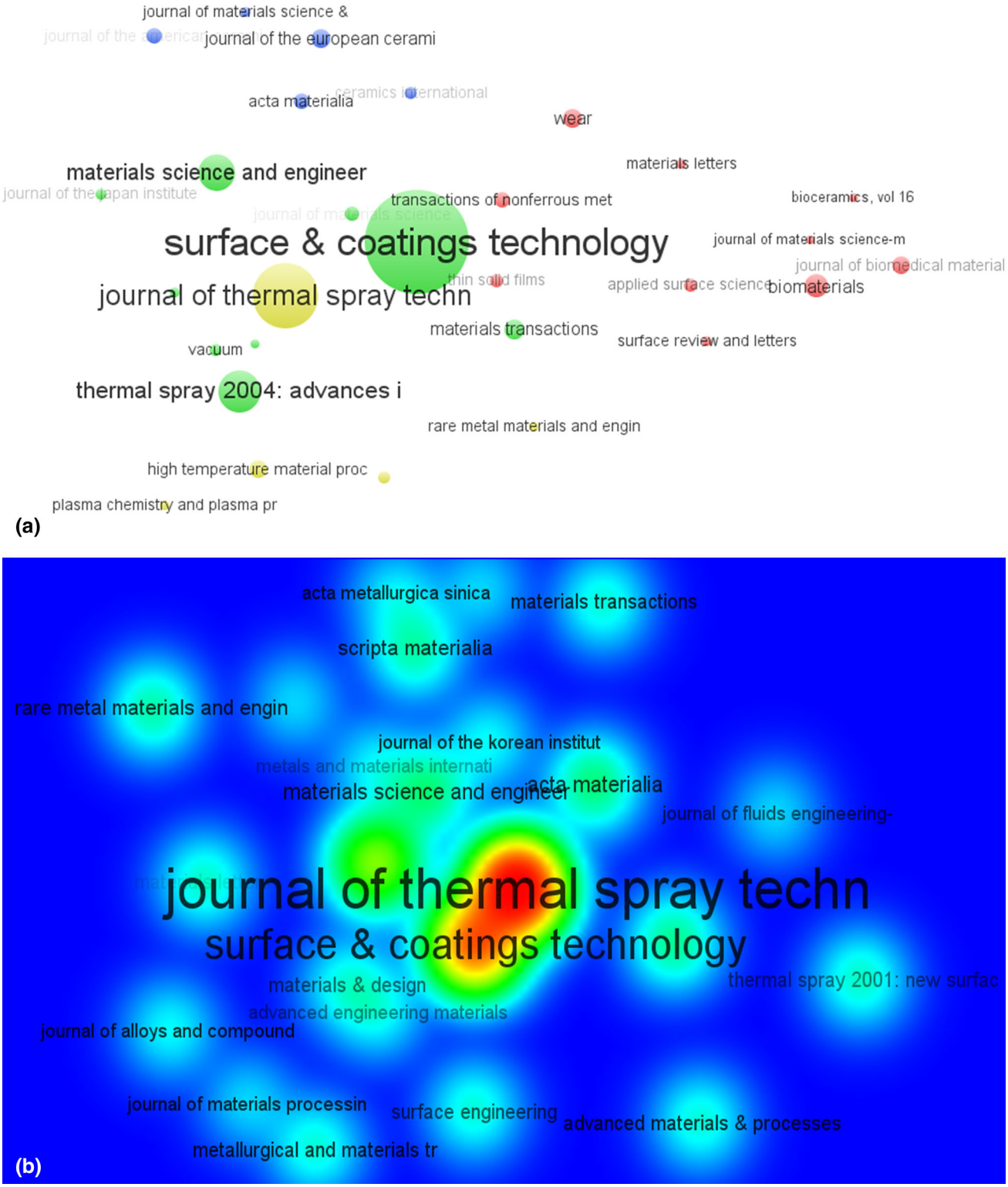


Fig. 5 (a) Top journals for thermal spray technologies (Source: Web of Science, Thomson Reuters). (b) Top journals for cold spray technology (Source: Web of Science, Thomson Reuters)

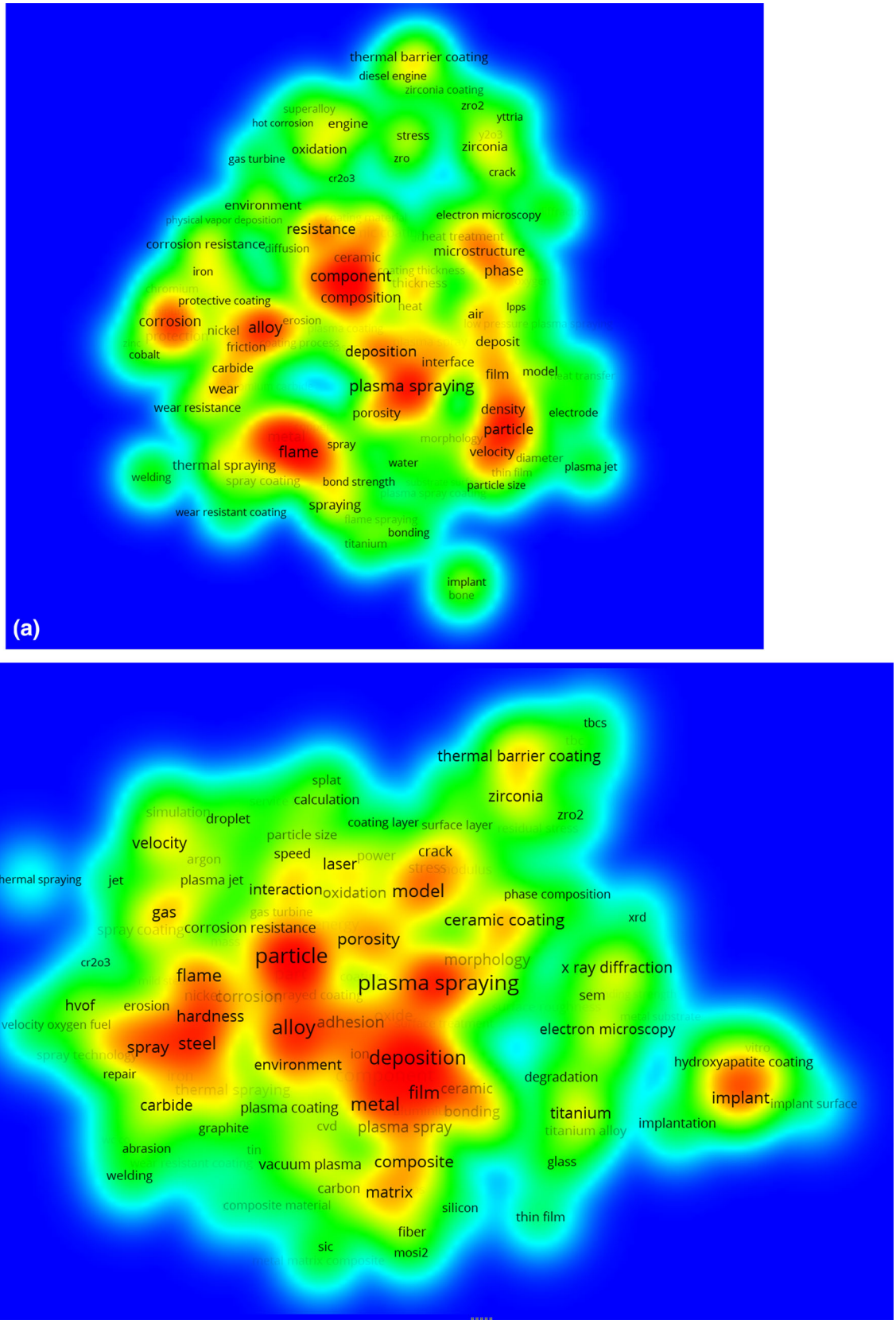


Fig. 6 Terms used in thermal spray coating technology publications published in different time periods. (a) 1985-1990, (b) 1991-1995, (c) 1996-2000, (d) 2001-2005, (e) 2006-2010, (f) 2011-2015

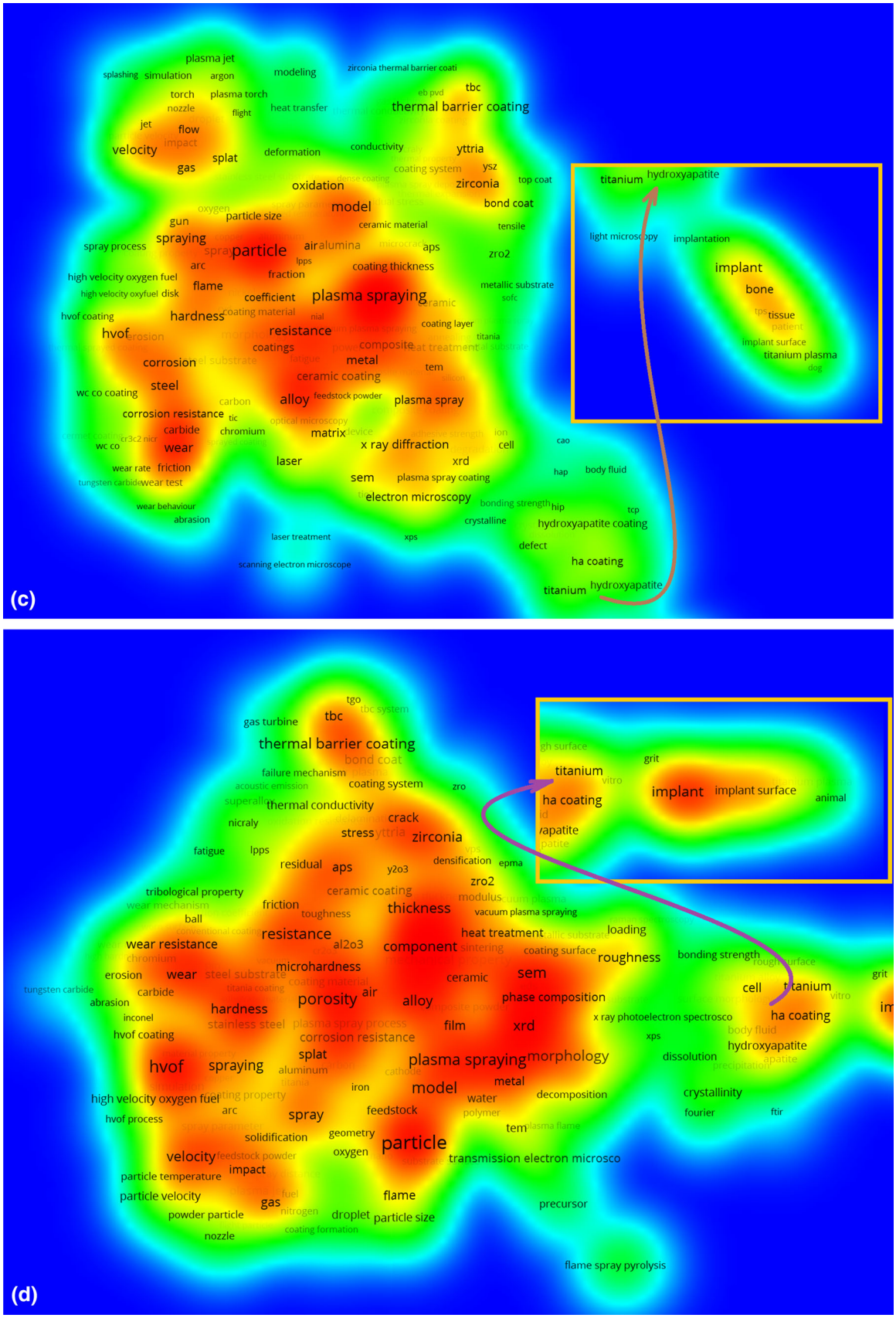


Fig. 6 continued

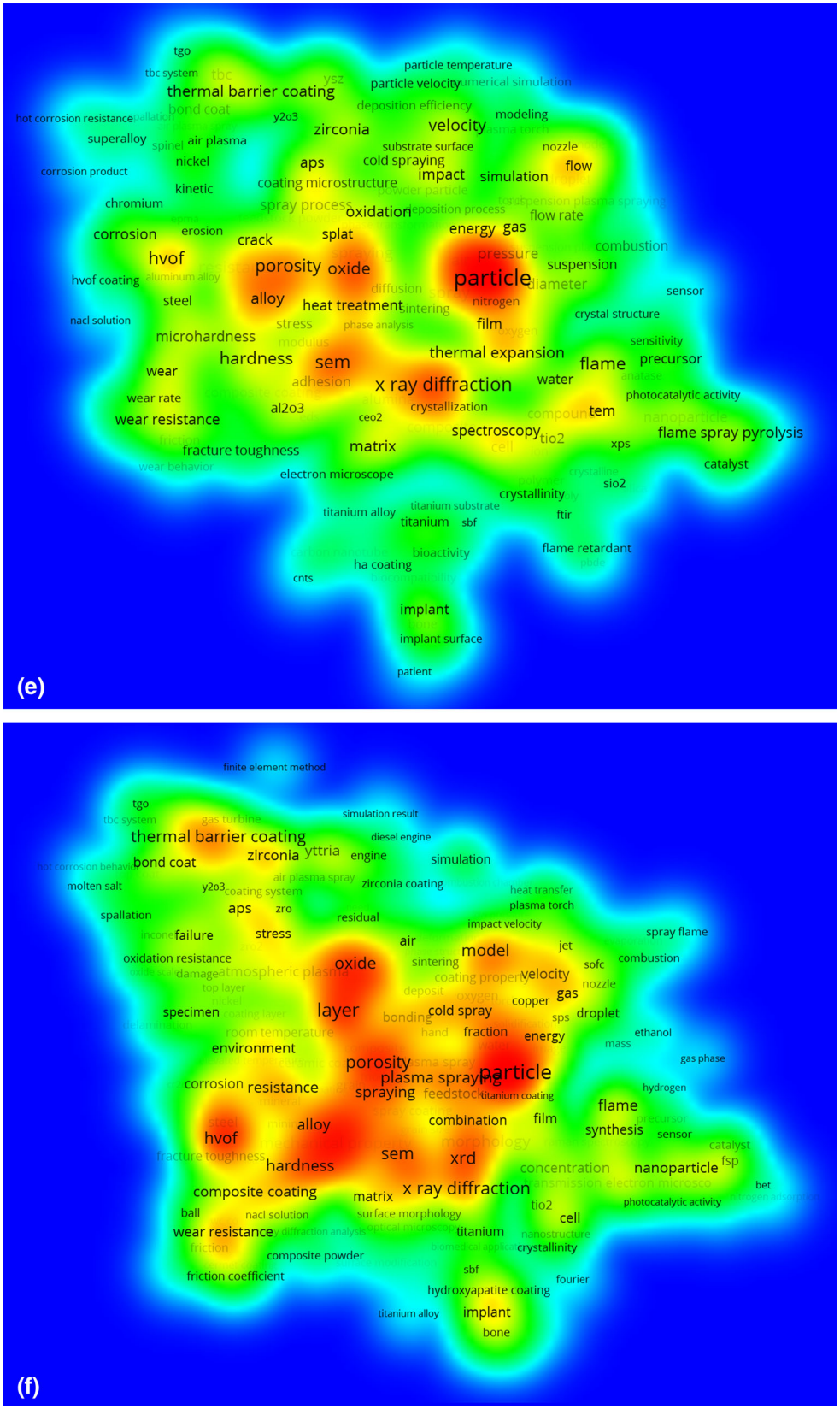


Fig. 6 continued

curred 15 times or more in the year were selected for mapping. The term ''cold spray'' can be seen in the periods 2006-2010 and 2011-2015 while it cannot be seen in the mapping for earlier periods. Similarly, the spot for HVOF emerged in the period 1991-1995, and become progressively larger in the mappings thereafter.

Summary

In the past 20 years, the number of research publications on thermal spray technology has grown steadily. The USA took a lead position in thermal spray technology research during the 1980s and the 1990s, while China was the dominant country over the last 10 years, reflecting the rapid rise in number of publications from the Chinese Academy of Science and the Xi'an Jiaotong University. *Surface & Coatings Technology, Journal of Thermal Spray Technology,* and *Materials Science and Engineering A* were the three most popular journals for publishing thermal spray research. However, for the emergent cold spray technology, the *Journal of Thermal Spray Technology* was the dominant journal for peer-reviewed papers. Thermal barrier coatings (TBCs) were the main research area within plasma spray coatings. The emergence of HVOF and cold spray has been the main development in thermal spray coating technology. Key areas for thermal spray technology based on citation impact, as indicated by the Field Weighted Citation Impact (FWCI) measurement, are energy, environmental science, and chemical engineering.

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