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SPRINT RA 372 Increasing European industrial awareness of ion implantation as an effective surface treatment

R.J. Rodríguez [a], N.J. Mikkelsen [b], T.J. Tate [c]

[a] *AIN, E-31191 Cordovilla, Pamplona, Spain*
[b] *DTI Tribology Centre, Teknologiparken, DK-8000 Århus, Denmark*
[c] *Imperial College, Exhibition Road, London SW7 2BT, UK*

Abstract

This paper reports on an initiative, funded in part by the European Union, to increase the level of awareness and use of ion implantation as an effective surface treatment, principally for tooling applications. A consortium comprising AIN (Spain), DTI (Denmark) and Imperial College (UK) was formed in 1991 and awarded a SPRINT (Specific PRojects for INtracommunity innovation Transfers) grant by the EU. Since then, the grant has been renewed twice, and has had a significant impact within the participating partners' countries. The project aims, by way of mailings, meetings, demonstrations, and seminars, together with a specially produced video and handbook of applications, to stimulate awareness within industry, with a view to increasing the use of ion-implanted tooling and the concomitant benefits of the technique.

During the project, a preliminary letter and questionnaire were sent to a total of more than 7000 companies, selected on the basis of industrial sectors, including users of machine tools, plastic moulds, paper and textiles knives, etc. Emphasis was placed on tooling rather than components. The level of use and awareness was evaluated from the 5% response to the initial questionnaire, and these data were used to refine the targeting of subsequent mailings and contacts.

In addition to the well-established niche applications, new areas are becoming apparent, including textiles and paper processing, machine tools for cutting composite and laminated materials, and stamping tools for sheet metal.

Care was taken to emphasise that ion implantation is one technique amongst many, and comparisons were offered with techniques such as PVD, CVD and traditional surface modifications, recommending implantation in cases where it has distinct advantages over other techniques.

As a direct result of this project, the level of awareness and commercial acceptance of the technique has increased within the participating countries, and it has been possible to identify possible new sectors. In addition, because the emphasis has been upon solving problems rather than applying one specific technology, the project has helped to emphasise the specific advantages of the technique, and has been positive in overcoming commercial reluctance, while avoiding competition with other treatments.

Keywords: Ion implantation; Surface treatment; Industry

1. Introduction

Unlike the big research and development programmes of the European Union, the SPRINT programme funds low-budget projects targeted to spread the use of already existing technology. Ion implantation treatments belong to this category [1,2,4–7,9], and a European consortium was created in 1991 with partners coming from two countries where ion implantation has been employed since the early 1980s (UK and Denmark) and a third partner which had just installed its first treatment centre, Spain. The consortium activities were carried out over the period January 1992–December 1995.

The project (contract number RA 372) was involved with technology transfer and raising the awareness of small and medium enterprises (SMEs) to the possibilities of surface modification. While it has concentrated on ion implantation, care was taken at all stages to stress that implantation is a niche application and is not always the most appropriate technology: where possible, alternatives were offered or suggested. The transfer has been principally to the SMEs, although because this is a European project, there has also been a transfer of information and views between the partners with respect to shared experiences and applications.

The project may be broken down into five main aspects:

(1) mailing lists, leading to user databases and statistics;
(2) teaching and promotion tools, including a video and handbook;

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(3) seminars and meetings;
(4) applications portfolio;
(5) establishment of a database of laboratories, companies and institutions interested in, or working in, ion implantation and related fields, mainly within Europe.

These aspects will now be examined in some detail.

2. Mailing lists

2.1. Mailed information and questionnaires

Specific brochures and leaflets were prepared in the three languages summarising the characteristics, advantages and applications of ion implantation treatments. Three main mailing campaigns were carried out in 1992, 1994 and 1995. The first one was addressed to all the relevant industrial sectors working with all kind of metallic tools (a wide selection of about 7000 companies in the three countries). The 1994 and 1995 campaigns were targeted at strategic sectors, and approximately 600 information packages were sent each year to the following kinds of companies: users of plastic moulds, manufacturers of plastic moulds, blade manufacturers, textile manufacturers, silver smiths, spring manufacturers, paper and label manufactures, TiN-coated tool users, aluminium machining companies, vegetable processing industries and metal box manufacturers. In Spain alone, approximately 1500 other companies are regularly informed of the project achievements and seminars, and so almost 10 000 companies in Europe have been made aware of the consortium activities.

Together with the informative leaflets, a questionnaire was included in the package, asking about industrial activities, tribological problems and surface engineering solutions employed, and the level of awareness and use of ion implantation and other alternative advanced solutions.

2.2. Analysis of answers and statistics

The return of the first questionnaire (1992) exceeded roughly 5%. Examining the answers, the level of awareness in Spain (after allowing for the common misunderstanding that ion implantation is ion nitriding) was less than 2%, far below Danish (14%) and British (21%) levels. The size distribution of the companies interested in the technology is shown in Fig. 1 and reflects in part the national industry size profiles. Therefore, it was considered relevant to establish different strategic approaches for the different countries.

The industrial sectors represented in the returned questionnaires belong mainly to the metal cutting, metal forming, machine manufacturing sectors, traditionally more involved with standard and non-standard surface

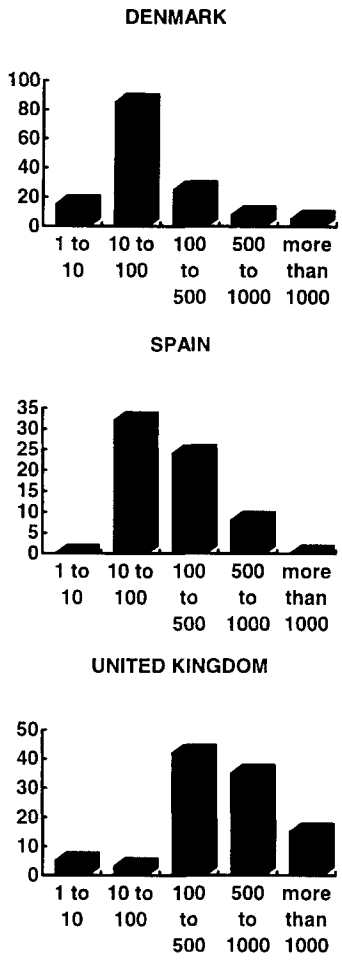

Fig. 1. Sizes of the companies that answered the 7000-addresses mailing of 1992.

treatments. Plastics comprise the next most important sector in the three countries, whereas some of the strategic sectors considered are weakly represented, as shown in Fig. 2.

Most important is the degree of awareness/use of different treatments shown in Fig. 3. Nitriding/carbiding are the most widely employed solutions in the three countries, followed by use of hard chromium and other electrochemical thick coatings.

Advanced thin coatings, mainly TiN and TiCN, come third among the preferred techniques. Differences arise between the three countries when considering the less usual treatments. In particular, ion implantation is mentioned in 9% of the Danish replies and 8% of the British, but only in 1% of the Spanish responses. This was the situation at the beginning of 1992.

As the selective mailings of 1994 and 1995 were targeted to chosen companies of specific sectors, a higher level of return and interest was detected (around 17%). However, as a result of the project activities and the articles published in industrial journals, the general level

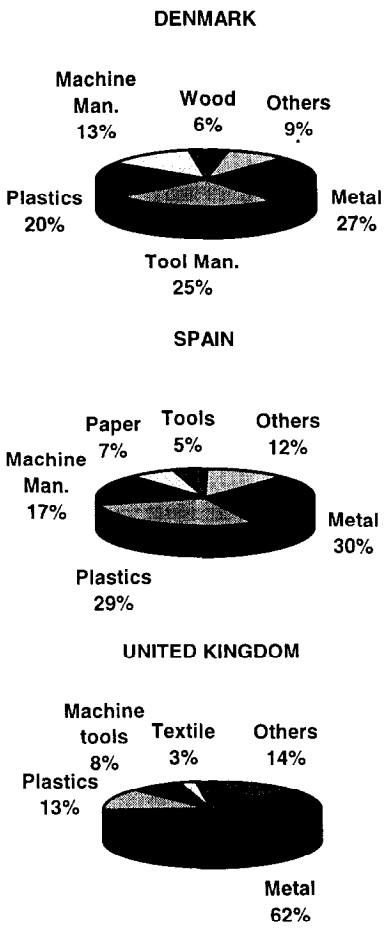

Fig. 2. Distribution of industrial sectors interested in the ion implantation treatments according to the 7000-addresses mailing of 1992.

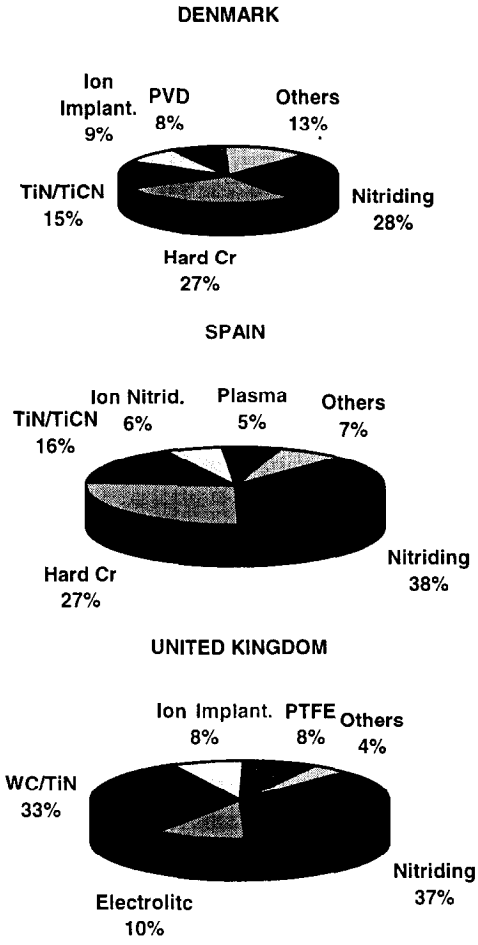

Fig. 3. Distribution of usual surface treatments employed or considered as good solutions by the companies, according to the 7000-addresses mailing of 1992.

of awareness increased, especially in Spain, which explains the increasing attention paid by the companies.

3. Teaching and diffusion tools

3.1. Informative leaflets

Informative leaflets were used (i) to explain the basic features of implantation process to non-scientists, (ii) to illustrate the advantages of implanted surfaces, and (iii) to enumerate the most common applications. Contrasts with coatings were frequently employed to characterise the ion implantation treatment. References to steel tools were the most common examples. Three years after the first contact brochures were sent out, almost 50% of the technical people professed some knowledge. Some confusion with other processes still occurs (mainly ion nitriding and TiN coatings) and the popular word "ionisation" is sometimes improperly used as the name of the treatment.

A better understanding has been reached by means articles in industrial journals, mainly by reporting the results obtained by other members of the consortium. Approximately 25 articles have been published in journals and magazines in the three countries, with results difficult to evaluate in the present time period.

3.2. Video

A SPRINT video was produced as an important dissemination tool. Filmed during the spring of 1994 in Pamplona (Spain), Århus (Denmark), London and Cambridge (UK), a 15-min tape (versions available in Spanish, English and Danish) explains, using animation, drawings and images of the real process and tools, the fundamentals of the process, the equipment, some usual and less common applications, some reasons for its effectiveness and the technical and economic advantages. Copies of the video were distributed to the most promising sectors during 1994 and 1995 with excellent results, and it has also been a help during company seminars.

3.3. Handbook

A more qualitative informative tool is the handbook, distributed to qualified industrial technicians as well as

researchers in order to propagate interest more widely. The handbook was planned for delivery together with the video; both share the same title: "Ion Implantation: the Invisible Shield".

This 40-page handbook is dedicated to explaining the different existing surface technologies, their areas of application, the advantages/disadvantages of ion implantation, the effects of the treatments and economic considerations. A science and technology resume is also included for the interested reader, and the second half is devoted to illustrate some 20 case studies and to summarise the actual degree of use of the treatment within Europe.

A open format has been chosen, which will allow the addition of future application sheets.

4. Seminars and meetings

The distribution of printed and visual information must be complemented by direct contact between the technological centres and companies. Individualised visits and meetings are the ultimate step before trials and demonstrations, but previous contact have been achieved by means of seminars.

Three kind of seminars have been carried out during the project: (i) sector seminars, focused on companies working in the same sector or in complimentary sectors (e.g. plastic mould users and plastic mould manufacturers); (ii) regional sectors, open to all kind of companies working in the same area; and (iii) specific seminars targeted at technical workers of one specific company.

About 30 seminars have been carried out in 20 locations within the participating countries. The global participation can be estimated as 800 persons, coming from 500 companies.

The largest seminar was given in Pamplona, Spain, in September 1994, with title "First European Symposium on the Present and the Future of the Ion Implantation Treatments". About 50 delegates, mainly from Spanish industries but also from technological centres in five European countries participated in a two-day programme, in which the fundamentals, equipment, economic aspects and practical applications were discussed and explained.

5. Applications portfolio

During the project period, a number of trials and demonstrations was carried out in the three countries, in the well known niche sectors (plastic moulds, plastic injectors, tin can tooling) and in some exploratory new sectors (food, paper, machine tools for special purposes, textiles). Intra-partner information transfer has played an important role both in sharing successful results in unexplored fields and convincing end users of the efficacy of the treatment.

An applications portfolio has been developed, detailing kind of application, tool material, implantation recipe, lifetime increase and other advantages, along with some economic indications in relation to tool costs, implantation costs, lifetime increase and savings in tool costs and downtime costs. A wide resume is included in the handbook and illustrative examples of accountancy savings are shown in both the video and the handbook. Other engineering surface solutions are also suggested when they are technically or economically advantageous.

Although most trials and demonstrations were for typical tooling problems, there is also a list of emerging applications in components; for example in the textile sector an increase of 150% in the lifetime of many cheap blades can make the production of long single lengths of material (e.g. carpets) possible. Another example is blades for peeling asparagus in automated machines. The increase in edge life time by six times avoids the need for resharpening during the asparagus processing and automated machines are more suitable for export to Third World countries where maintenance is more difficult.

6. Ion implantation agents database

As an extra product of the SPRINT activities, a database of institutes, university groups, subcontracting companies and ion implanter manufacturers was created after sending out more than 600 questionnaires, mainly to the participants of the IBMM '92 conference at Heidelberg. Although at the beginning the database was envisaged for EU centres, it was definitively extended to centres around the world. The database lists complete addresses, the name of a contact person, available facilities, kind of activity and the main fields of interest. It is expected that diversification and further enhancement of this database will contribute to increasing interest in other applications, and, mainly, interest in industrial applications of ion beam modification of materials, which is the objective of this activity.

Although some of the main laboratories are not included in the current edition of the database, 135 addresses, belonging to 100 cities of 29 different countries are included. As expected, European representation is still the highest, as a result of the propagation of the activity within the EU.

In the last year of the project, electronic mail was included as a diffusion tool to organise a network of centres interested in ion implantation applications, in order to share information and scientific databases.

7. The future of the ion implantation treatments

7.1. Industrial concerns

Clearly, while technological advances may enhance the rate of growth of ion beam treatments, this project has highlighted many of the industrial concerns about employing new technologies.

The usual discourse on ion implantation begins by enumerating the characteristics and advantages, which can be summarised in ten points: (1) significant improvements of lifetime and performance of tools; (2) low-temperature treatment; (3) no delamination risk; (4) no dimensional changes; (5) no surface finishing changes; (6) can be applied to previously treated surfaces (nitriding, hard chromium, TiN); (7) can be selectively applied; (8) provides specific solutions for the different problems; (9) it is a highly controlled treatment; and (10) it is a clean technology.

Despite positive responses to these messages, an important list of obstacles is often presented: (1) impossibility of using the usual hardness scale for reporting the implantation effects; (2) difficulties in predicting the exact increase of lifetime with new applications; (3) impossibility of treating internal parts of tubes, pipes etc.; (4) reservations about applicability to large batches; (5) the invisibility of the treatment; and (6) the price in comparison with traditional treatments.

As a pragmatic synthesis it is necessary to agree that, given the present technology, routine use of ion implantation is mainly restricted to: (1) expensive tools; (2) critical components; and (3) components that are difficult to replace, although it is important to be aware of the possibilities of the treatment for low-cost tools and components once further developments in the technology have lowered treatment costs.

The final problem concerns demonstrations, because of unexpected obstacles such as (1) poor quantification of performance, (2) non-existent lifetime data, and even (3) loss of the treated tool. The long lifetime of treated samples is a further obstacle to the achievement of quick demonstrations, and proving times can thus be very long for centres and companies working in diffusion of the treatment. The result is that the initial growth of industrial awareness can be very slow.

7.2. Coordinated action

It is probable that technological developments will further enhance the accessibility of ion beam treatments, and dedicated, automated machines with advanced beam control, or broad-beam high-current machines or, alternatively, plasma immersion implanters will be developed [3,8,10]. Ion implantation is well developed and commercialised in its present niche applications, mainly plastic moulds, medical implants, cutting and forming tools for metalboxes, and also in an increasing number of emerging sectors, some of which have been described in this report. The search for new applications fields is continuing.

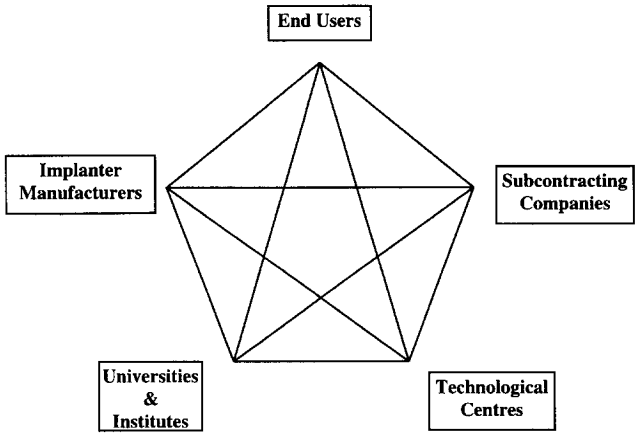

Fig. 4. The five agents of the ion implantation treatment progress.

Coordinated action, as represented in Fig. 4, is necessary for further advances and this must represent the points of view of the five sectors represented (Universities, technological centres, implanter manufacturers, subcontracting companies and end users). Although this paper reports only on experiences gained in Europe, transcontinental cooperation must continue.

8. Conclusions

High-level technology transfer activities have been developed over four years by a European consortium of technological centres in the frame of the EU SPRINT programme. The activities have enabled about 10 000 companies in three European countries to learn about ion implantation technology and valuable experience has been gained concerning possibilities of a wider use of this treatment.

While technological developments will provide easier access to the treatment, the immediate future seems oriented to niche applications where rentability has been proven with present-generation machines. The search for new niche sectors continues, and the technology must be presented in such a way that it complements rather than competes with other solutions provided by modern surface engineering.

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