"Arc and Plasma Spraying Today and in the 90th"

Prof. H.D. Steffens

Question (*Dr. S. Amada*) :

In these years, I am studying about ceramic coatings by plasma spraying, particularly its pore structures and its application to heat engines. Please allow me to ask my questions based on that point.

1. To improve plasma spraying technique it is required that the spraying process should be clarified based on the theoretical model, in particular, behavior of plasma jet, interactions between plasma jet and introduced particles, velocity and temperature of the particles residencing in jet, flattening process of the particles on the substrate and so on. What do you think of my comment?
2. In applying ceramic coatings to heat engines, such as TBC and insulating components in diesel engines, zirconia is the most attractive candidate because of low thermal conductivity. To realize, there exist several problems, for example, low adhesion strength, limited thickness of coating layer, instability of partial stabilized zirconia under hot flame. Is there any powerful approach to get over these barriers?
3. To drive researches and developments of plasma spraying technique further, we must have effective and simple evaluating methods of coating layer, which should be not only nation-wide but also world-wide acceptable methods. Do you have any idea about this point?
4. You presented recently developed hardwares of plasma spraying, for example, low pressure chamber, several stabilized torches, vacum arc-spraying unit and so on. It may consider that plasma spraying can be also assisted by other heat source such as laser beam, so called a hybrid plasma spraying unit operated by more than two heat sources. I want to ask you about this approach?
5. They are trying to put an after teatment of plasma spray coating by HIP, laser glazing and so on to improve the physical and mechanical characteristics of the coatings. Can we expect these techniques?
6. The applications of plasma spraying technique is rapidly growing these days to various fields. However its market is still limited. The market extension can be prevented by several problems, typical one of which are cost performance and quality of coating layer. How do you think of plasma spraying technique in future?

Answer (*Prof. H.D. Steffens*) :

1. There is a large variety of possible ceramic coating systems available, after years, however, till no Zirconia (partially stabilized) shows best overa properties. There are possible improvement in proces ing as well as possible selection in order to give bette adhesion to the base material and avoid crack fo mation in or paralled to the surface.
   I wonder whether there will be another ceramic syste to replace the Zirconia coatings in the near future. don't believe.
2. Problems in the application of sprayed coatings mainl arise due to inadequate coating properties and the lac of property control, so one of the most urgent develo ment should be that of easy-applicable methods o non-destructive testing. This coatings would no longe be unpredictable in behaviour under enhanced sever conditions in respect to adhesion, crack formatio existence of pore clusters etc. Another step is th development of equipment and material based o scientific investigation of processing and governin process parameters; away from the try-and-erro methods.

Composition and structure stability of ceramic coating ar of governing influence on coating performance and highl dependent on kind of applied production process an process parameters. Then different processes provide quit different conditions, for instance on temperature an velocity. With the high speed processes (like D-gun providing much lower particle temperatures than the usu plasma spray processes. In the future, the selection o process will no longer be subject of personal in intuitio but will have carefully to consider all these aspects i order to obtain optimum coating properties. I see two-way use of computers in thermal spraying, the firs being a means of control of process parameters. There i an obvious necessity for that and it is being done alread as may be seen in JWRI-labs. The other use will be withi an expect computer system where-on the base of dat bank information and special software-a proper design o coatings meeting service conditions best, may be carrie out.

"Formation of Ceramics Coating by Laser Proces ses"

Dr. M. Wehr

Question (*Dr. N. Yasunaga*) :

Laser surface modification technologies have not been s much adopted yet in practical production in spite of thei attractive features about which Dr. Wehr has presented This means that these new technologies should be muc more brought up to develop into future businesses. Al

these new processes have their own merits and devrerito compared with conventional other processings. Some countermeasures must be necessary to improve their potential.
My question is what should we do in order to improve these new technologies for applying to pratical use in production. Please point out one or two important points which we should consider and solve for improvement of each process Dr. Wehr has classified.

Answer (*Dr. M. Wehr*) :
As far as I know, some of the processes I have described are already in development, and will be on production line (in less than 2 years) in a near future, but nor is the field of ceramics coating (it means that there is no more problems for certain of these processes, in some companies). It is the use of the stellite coating of turbine blades by powder injection processes assisted by laser, process which is already in development. It is also the case of deposition of metal by laser CVD for mask depositing, and this process is already sold on the market.

"Formation of High Function Ceramic Surface by Ion Implantation"

Prof. N. Iwamoto

Question (*Dr. Iwaki*) :
I am much interested in your work, and I think you suggest the possibility that a certain ceramics transforms other types of ceramics by high fluence ion implantation.
I think that there are two big categolies in the fields of surface modification of ceamics by ion implantation; one is the metallization of the near surface layers of ceramics by metal ion implantation and the other is the transition of types of ceramics by high fluence ion implantation with light ions such as carbon, nitrogen and oxygen.
Your report is an example of the latter case, you introduces preliminary experimental results with microcharacteristics of nitrogen implanted SiC measured by means of RBS, XPS, SIMS and laser Raman. It seems that the results indicate the formation of nitrides, oxides, oxinitrides, carbonitrides, graphite and so on. We have investigated the surface layer modification of non-oxide ceramics such as AIN and SiC by metal ion implantation with a high fluence. We also found such similar results as the formation of graphite and oxides in SiC due to ion implantation.
In order to clarify the formation of compounds in nitrogen implanted SiC, I will ask you tnree questions.
1. It seems that the RBS spectra for nitrogen implanted SiC, that is the as-implanted SiC, indicate the enrichment of carbon near the surface layers. Is it true?
2. You explain that the XPS spectra for Si_{2p} indicate the occurrence of oxidation. Please show us the ratio of compositions for all of the elements in nitrogen implanted SiC and the XPS spectra for O_{1s}.

Lastly, are your experimental results desirable from the standpoint of improvement of physical, chemical and mechanical properties?

Answer (*Prof. N. Iwamoto*) :
1. As shown in Fig. (7), we can conclude that the decomposition of SiC, that is to say, to form free carbon and silicon occurs with nitrogen ion implantation at the surface of specimen. Also it is recognized that the higher the ion implantation is, the greater free carbon forms.
2. As shown in Figs 4(a), (b) and 5(a) and (b), it can be seen the formation of SiO_2 with after-heat-treatment of 1273°C x 1hr. (Si_{2p} value=103.5eV)
   In Fig. 4(a) and (b), the only formation of SiO_2 with the disappearance of Si_3N_4 can be determined. Of cource, in Fig. 4(a) and (b), the relation between the ratio of Si_3N_4/SiO_2 and the change of after-heat-treatment temperature is given so that the former can be calculated by using convolution method.
3. Though the author did not present in this publication the improved behaviors of the mechanical properties such as wear-resistance, hardness and fracture toughness with ion implantation in SiC, this technique is superior one for the improvement of physical, chemical and mechanical properties of every matter.

Concluding Remarks

Prof. H.D. Steffens and Prof. N. Iwamoto

In session II, the progress on the surface modification procedures have been treated.
At first, Professor Steffens of Dortmond University in West Germany presented the paper titled "Arc and Plasma Spraying Today and in the "90th". He emphasized that arc and thermal spraying technologies were becoming more and more important technique to give special properties such as high resistance to corrosion and wear to materials. The production of composite texture composed from austenitic steel fiber embedded into MCrAlY alloy phase with after-hot isostatic pressing was introduced. Following, he said that the application of vacuum plasma spraying for MCrAlY coating on turbine blade was important. However recent endeavours to apply this procedure to coat reactive materials such as titanium and tantalum have been paid. He presented new plasma spraying