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Osaka University

“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 residing 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, vacuum 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 treatment 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 now Zirconia (partially stabilized) shows best overall properties. There are possible improvement in processing as well as possible selection in order to give better adhesion to the base material and avoid crack formation in or parallel to the surface.

I wonder whether there will be another ceramic system to replace the Zirconia coatings in the near future. I don't believe.

2. Problems in the application of sprayed coatings mainly arise due to inadequate coating properties and the lack of property control, so one of the most urgent developments should be that of easy-applicable methods or non-destructive testing. These coatings would no longer be unpredictable in behaviour under enhanced severe conditions in respect to adhesion, crack formation, existence of pore clusters etc. Another step is the development of equipment and material based on scientific investigation of processing and governing process parameters; away from the try-and-error methods.

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

“Formation of Ceramics Coating by Laser Processes”

Dr. M. Wehr

Question (*Dr. N. Yasunaga*) :

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

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 catogolies 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 micro-characteristics 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 AlN 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 three questions.

1. It seems that the RBS spectra for nitrogen implanted SiC, that is the as-implanted SiC, indicate the enrich-

ment 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 SiO₂ with after-heat-treatment of 1273°C x 1hr. (Si_{2p} value=103.5eV)

In Fig. 4(a) and (b), the only formation of SiO₂ with the disappearance of Si₃N₄ can be determined. Of course, in Fig. 4(a) and (b), the relation between the ratio of Si₃N₄/SiO₂ 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 Dortmund 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