Temperature measurements of different materials in various plasma conditions

Temperature measurements of different materials in various plasma conditions

by LENKA ZAJÍČKOVÁ, MILOŠ KLÍMA and JAN JANČA

Abstract

The behaviour of temperatures of various solids immersed into a *r*adio *f*requency (rf) plasma is being studied. The discharges were generated in a tubular reactor with external electrodes. The temperature was measured by mercury thermometers inserted into the caps of various materials and by thermocouples sealed to a variety of objects including some historical silver coins partially covered with a corrosion layer. The monitored temperatures did not exceed 180 °C and reached constant values at least after one hour of exposure. Measurements have shown that the object temperature depends on the material and the spatial position of the artefact in the plasma reactor as well as on the gas mixture used. Experiments showed that thermocouples caused additional heating of the objects especially in the case of objects with small masses.

Introduction

Measurements of object temperatures and their corrosion depositions during plasma treatment are important for a variety of reasons. Historical objects being sensitive to degradation by heating, conservators have to know its temperature during plasmachemical treatment. In the recent paper we have measured the temperature of various materials immersed in tubular plasma reactor with external electrodes. Simultaneously the same reactor is used for plasma treatment of archaeological artefacts.

Experimental

The tubular reactor consists of a *Simax glass tube* with an inner diameter of 8 cm and a length of 90 cm. It has a

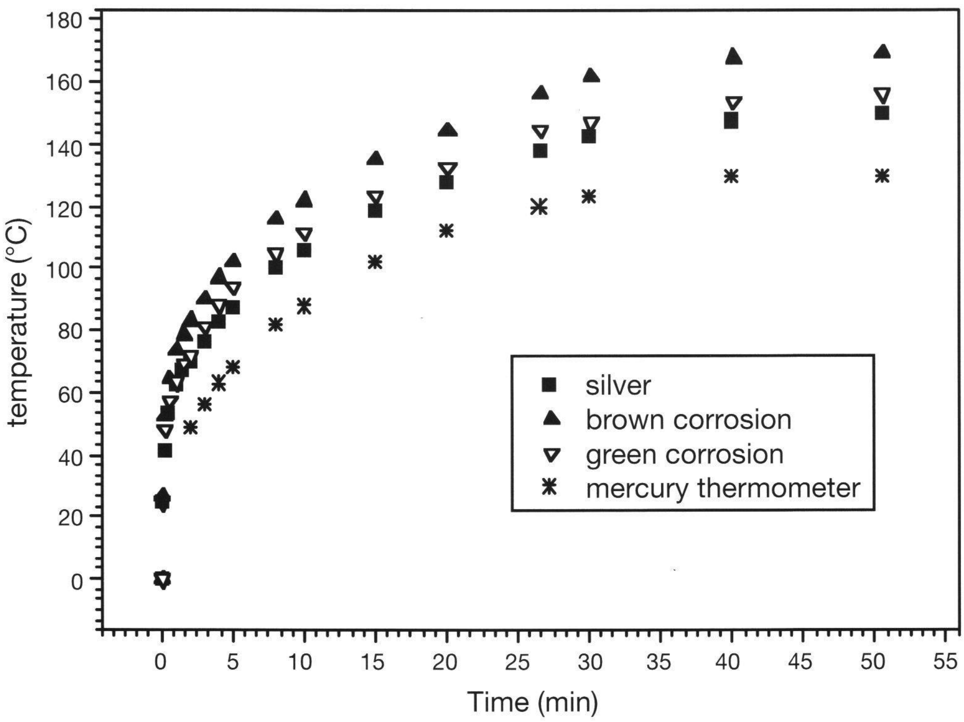

Fig. 1 Temperature measurement during plasma treatment of silver coins in hydrogen plasma (p = 100 Torr, Q = 30 sccm, P = 200 W). Three thermocouples were sealed to the different parts of the coin.

removable brass electrode of 50 cm in length as well as brass flanges. The lower electrode was powered by a frequency of 13.56 MHz (Megahertz) and the upper was grounded. The archaeological artefacts were placed on glass rails in the centre of the tube. The inlet of the gases used (air, hydrogen and argon) is situated in the flanges on the opposite side of the rotary pump outlet. Mercury thermometers fixed inside on glas rails measured the plasma temperature. Some thermometers were inserted into the caps of various materials such as iron, copper, brass and aluminium. At the same time three thermocouples were used in different arrangements, one standing free in plasma, one fixed inside of the glass capillary in direct contact with plasma and one being inside of the metal cap, sealed to the glass wall.

Results and Discussion

Stanislav Vepřek[1] already explained the different temperatures of various solids exposed to a nitrogen plasma. Our measurements in various gas mixtures confirmed these results. The time dependence of the object temperature is characterized by a stepwise increase during typically 10 to 15 minutes followed by a slow increase until the temperature reaches its plateau at least after one hour. The reproducibility of the object heating in argon and in hydrogen plasma was demonstrated by repeated temperature monitoring. The standard deviation of the object temperature after one hour is equal or less than 3 °C. However the object temperature will strongly change when the tube reactor is covered by some deposits. We have observed the influence of the gas flow rate on the object temperature for argon plasmas. The difference between the highest and lowest temperature measurement was 41 °C at an argon flow rate of 20 sccm and 14 °C at a rate of 15 sccm, the thermometer being inside of the aluminium cap. With a decreasing argon flow rate the temperature inside of the aluminium cap decreased from 179 °C to 154 °C. At a constant value of the gas flow rate of 20 sccm the mixture of gas from argon to air and hydrogen is being varied. The temperature difference observed for the various caps was 37 °C for air and only 12 °C for hydrogen gas discharge. The homogeneity of the object temperature for an air discharge was studied in a previous work[2]. We have found that the homogeneity of the temperature at a higher gas flow rate is better than at lower flow rate.

During the hydrogen plasma treatment of silver coins, temperature monitoring was performed additionally, the artefacts being partially covered with two corrosion films. Three thermocouples were sealed to the different kinds of the corrosion surface, one to the pure silver, one to the green and one to the brown corrosion layer. The increase of various temperatures during the plasma treatment demonstrates the individual, but similar behaviour of these different layers (Fig. 1).

Conclusions

Measurements in the tubular reactor demonstrate that the object temperature depends strongly on the kind of the object material, the gas mixture and the spatial position in the tubular reactor. During our experiments the correctness of the thermocouple measurements could not be verified independently. It will be necessary for further experiments to verify thermocouple measurements simultaneously by means of another method, e.g. by a pyrometer temperature measurement.

Acknowledgement

The present work was supported by the Grant Agency of the Czech Republic, contract 202/94/0490 (PACS 52.80-s).

REFERENCES

1 Stanislav Vepřek, *Heterogeneous reactions in non-isothermal low pressure plasma: preparative aspects and applications*, in: Pure & Appl. Chem. 48, 1976, p. 163.

2 Lenka Zajíčková / Miloš Klíma / Jan Janča, *The Study of discharge and substrate parameters important for plasma deposition,* in: Proceedings of WDS'96, Praha 1996, p. 144.