April 5-7, 2004 NAGOYA, Japan

International COE Forum on Plasma Science and Technology

Technical Session
Proceedings

21st Century COE Program : Plasma-Nano
"Information Nano-Devices Based on Advanced Plasma Science"

Nagoya University, Nagoya, Japan

Non-Thermal Plasma Influence On Tobacco Smoke

M. Morvová[1], I. Morva[1], K. Hensel[2], J. Pawłat[3], Z. Košútová[1]

[1]Institute of Physics, Comenius University, Mlynská dolina F2, 84248 Bratislava, Slovakia
[2] Department of Plasma Physics, Comenius University, Mlynská dolina F2, 84248 Bratislava, Slovakia
[3] School of Science and Engineering, Saga University, Honjo-machi, 840 Saga, Japan

Possibility of the decrease of the harmful gaseous compounds in the tobacco smoke under the effect of non-thermal plasma of DC corona discharge of both polarities were investigated. The changes of the gas composition in time were monitored and the by-products identified. The main end-product is nicotine amid acid, which sediments on the electrode, and gaseous by-product namely propylene and methanol.

1. Introduction

Environmental tobacco smoke is a highly diluted combination of mainstream smoke (MS) exhaled by smokers and sidestream smoke (SS) released directly from the burning tips of cigarettes. The health effects of cigarette smoking have been subjected to intensive scientific investigation since the 1950s. Smoking is linked to leading causes of chronic illness and premature death, including lung cancer and other malignancies, heart disease and stroke, and chronic obstructive pulmonary disease (e.g., bronchitis and emphysema). [1]

The aim of this article is

• to examine the possibility of the decrease of the harmful gaseous compounds in the tobacco smoke (on the basis of previous work e.g. [2])

• to explain the chemical changes with nicotine (on the basis of step by step kinetic measurements [3]).

2. Experimental

Measurements were made for both polarities of DC corona discharge. In order to analyse the gaseous mixture before/after the discharge action a gas cell discharge tube was used (see Fig.1). The mainstream smoke was pumped through gas cell discharge tube.

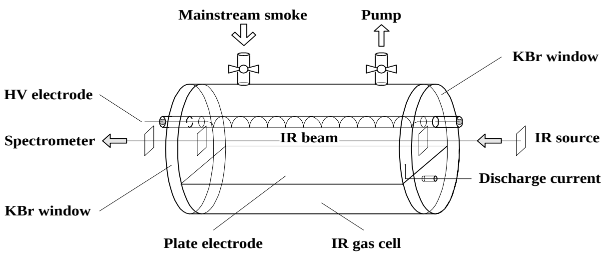

Fig.1. Gas cell discharge tube

In the appropriate moment in time (when the chamber seemed to be filled with a smoke) the valves were closed. Then the DC corona discharge was applied in the discharge tube. The IR absorption spectra of the gases were analysed directly in the discharge chamber each 30 s of the discharge action up to 7 minutes (step-by-step kinetic measurements).

The main advantage of this method is that the intermediate products can be observed too (in a classical method they can react on the wall of the sample take away tubes) .

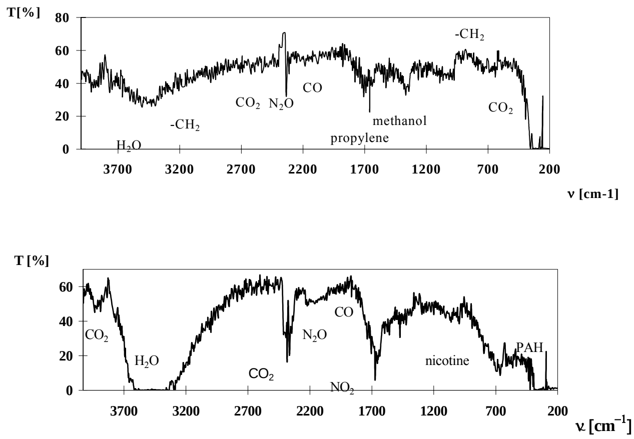

Fig.2. IR absorption spectra of the smoke before (upper spectrum) / after (lower spectrum) negative corona discharge action (for 7 mins).

IR absorption spectra of the introduced smoke, gaseous products after negative corona discharge action (during 7 mins) and reflection spectrum of the non-stressed electrode are in Figs.2, 3.

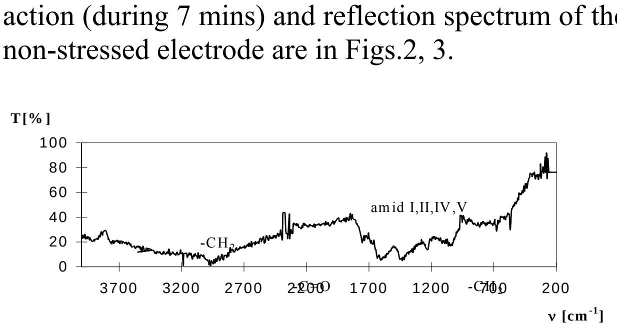

Fig.3. IR reflection spectra of the plane electrode after corona discharge action (7 mins).

2.1. Gaseous products

The decrease of all gaseous oxides is indicated from the IR spectra, namely CO (2065 cm^{-1}), CO_2 (2325, 670 cm^{-1}), NO (1860 cm^{-1}), NO_2 (1645 cm^{-1}). Especially the decrease of the CO_2 is important, the concentration of CO_2 in the products after corona discharge action is below of the concentration of CO_2 in the ambient air (350 ppm). The decrease of the concentration of compound containing benzene ring is evident, too (Kekule band at 1580-1600 cm^{-1}) and the polycyclic aromatic compound (deformation range between 700-200 cm^{-1}).

Nicotine appears in the IR spectra as a C-N-C group in pyrrol or pyrimidine ring (1000-1300 cm^{-1}), respectively.

2.2. Nicotine analyses

For the detailed study of nicotine decomposition a corona discharge was made over nicotine solution. This solution was gained by elution of one cigarette in a 60 ml boiled water. The plate electrode was immersed in the solution and the HV electrode was over the fluid level. The corona action was applied for 30 minutes. The IR reflection spectrum of the non-stressed electrode after corona discharge action over nicotine solution is in Fig.4.

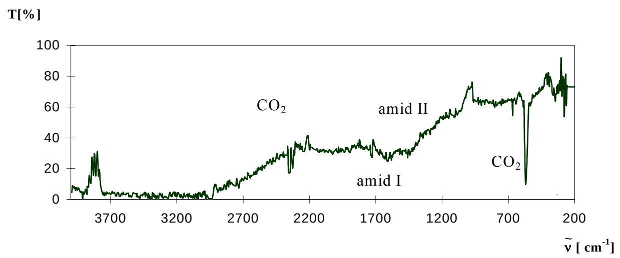

Fig.4. IR reflection spectra of the electrode after discharge action in discharge cell.

Both the 'sediments' without and with corona discharge action were separated from the water and after drying were analysed by KBr pellet making technique. The spectra are in Fig.5.

3. Conclusions

It is commonly known, that nicotine penetrates into the body of smoker gradually and the liver oxides the soluble nicotine into 'not so harmful' cotidine (see Fig.6). Cotidine is soluble in water and is excreted by urine. From the figure is seen that the structural change in human body is made in position trans.

After DC corona discharge action on nicotine the main end-product is nicotine amid acid, which sediments on the non-stressed electrode. As a by-product gaseous propylene and methanol were observed (it can be seen from the comparison of IR

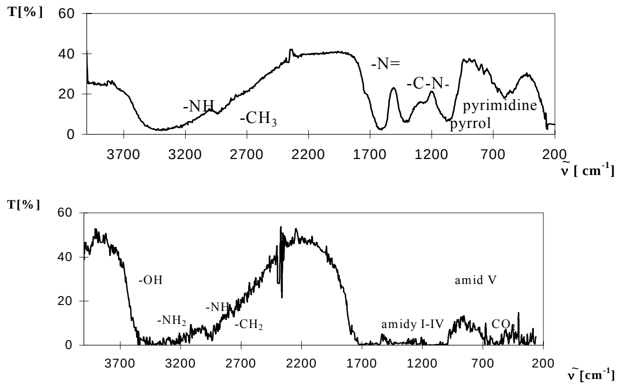

Fig.5. IR spectra from KBr tablet of nicotine compound sediments before/ after corona discharge action.

spectra of gases). From the more detailed study of the IR spectra of gases end electrode surface can be established, that the change of nicotine over goes in two steps. The first step is oxidation-reduction step, the second one is decomposition step. In the oxidation-reduction step characteristic deformation by electric field takes place, and the changes in position cis are caused by this step (CO^-, NH).

Amide of nicotine acid leads to formation of heterogeneous catalytic film, which rapidly influences the decrease of CO_2 up to very low values.

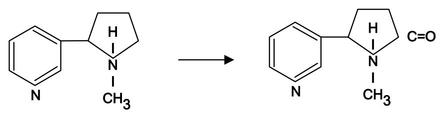

Fig.6. Decomposition of nicotine in liver.

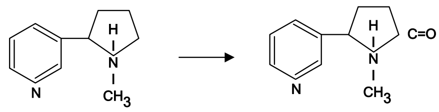

Fig.7. Decomposition of nicotine in corona discharge.

4. Acknowledgement

The authors wish to thank to the Agency for support of Science and Technology for financial support given to the project of bilateral Slovak-US cooperation No. 027-2001 A part of this work was also supported by the Grant of Japanese Society for Promotion of Sciences, Japan.

5. References

[1] C. S. Redhead, R. E. Rowberg, CRS Report for Congress Environ. Tobacco Smoke and Lung Cancer Risk, CRS / The Library of Congress (1995)

[2] M. Morvová, J. Phys. D. **31** (1998), 1865–1874

[3] M. Morvová, I. Morva, M. Kurdel, Contrib. Plasma Phys. **33** (4) (1993) 285-292.