SPATIAL HETEROGENEITY OF CHEMICAL COMPOSITION IN SEALED-OFF CO_2 AND CO LASER PLASMAS

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ABSTRACT

Chemical composition of different discharge regions has been investigated for low-pressure CO_2 and CO laser mixtures. The distribution of neutral (stable and unstable) discharge products along the discharge axis has been measured and the effect of cathode material on plasma processes has been demonstrated.

1. INTRODUCTION

Plasmochemical processes in electrodischarge molecular ir lasers have recently become a subject of wide interest (1). Most detailed information is available on the variations in gas composition under discharge for the low-pressure CO_2 lasers. It was indicated earlier for carbon dioxide dissociation in a sealed CO_2 laser discharge (2) that the heterogeneous processes are essential and the CO_2 dissociation degree depends on cathode material. However, on the basis of few experimental data it was difficult to construct a detailed picture of discharge product distribution along the tube. It was also interesting to measure the discharge product distribution in CO laser mixtures This work presents results of mass spectrometric investigation of plasma composition for different regions of the glowing discharge typical for CO_2 and CO lasers.

2. EXPERIMENTAL

The experiment was carried out with an installation using a monopole mass spectrometer APDM1 (3). The sampling was performed directly from the plasma through a 80μm diameter hole. The water-cooled tube was 150cm long and 20mm in inner diameter. The electrodes could be moved inside the tube with respect to the sampling hole without breaking vacuum, the distance between the electrodes being of 25cm. Cylindrical platinum and tantalum electrodes, 25mm long and 10mm in diameter, were located on the axis of the discharge tube. The measurements of neutral (stable and unstable) products were conducted with a starting 1:1:8 mixture of CO_2-N_2-He and 1:10:0.07 mixture of CO-He-O_2 at pressure of 10 Torr and discharge current of 20mA. Pressure change due to leaking out to the mass spectrometer could be neglected

3. RESULTS

Fig. 1 a,b shows the results of measurements for the CO_2-N_2-He mixture in terms of CO_2, O_2, O and NO concentration dependences on the distance between the cathode and sampling hole, the CO_2, O_2 and O concentrations being given in per cent to the starting CO_2. Curves in Fig. 1a are obtained for both the cathode and anode made of tantalum frequently used as a material in sealed-off CO_2 lasers. It is seen that the CO_2 concentration falls near the cathode with respect to the positive column and anode regions where it is constant. A higher dissociation of CO_2 at the cathode is associated with the presence of more energetic electrons as compared to the positive column. Considerable concentration variations are observed for NO, O_2 and O near the electrodes. The NO concentration maintains constant along the positive column and falls close to the electrodes, more sharply at the cathode. Unlike it, the molecular oxygen is decomposed in the positive column and re-formed near the electrodes, more efficiently also at the cathode. The O atom concentration decreases to the electrodes that is in accordance with earlier conclusions about the efficient recombination of oxygen atoms on a metal surface. The greater recombination rate on the cathode is likely due to its higher temperature as compared to the anode because of ion bombardment.

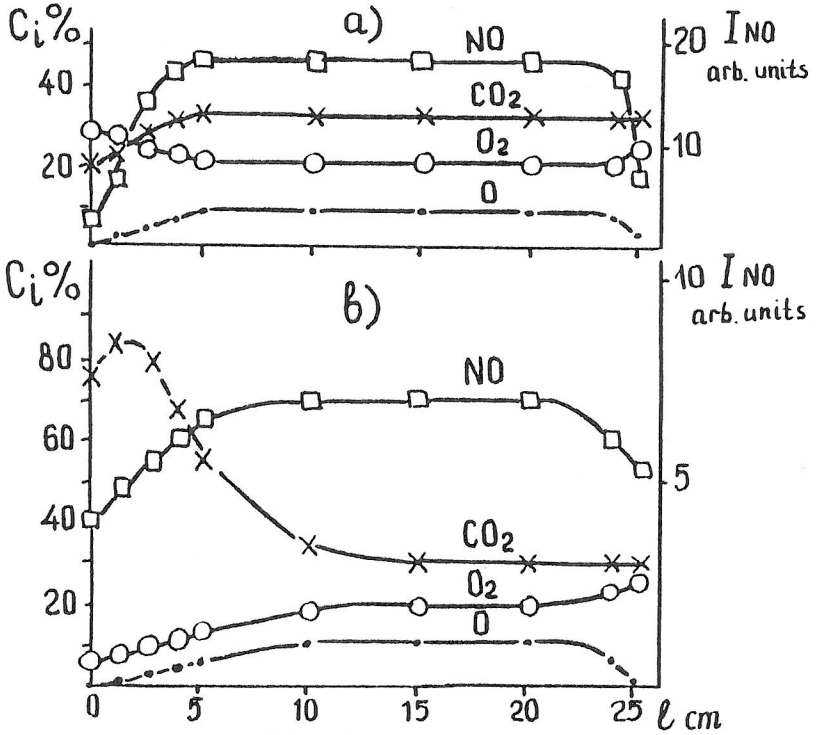

Fig. 1

Fig. 1b shows similar dependences for a platinum cathode, the anode material being tantalum. The curve behavior is essentially different. The CO_2 concentration increases strongly near the cathode ($l<4$cm), decreasing to the positive column region and remaining constant at $15\text{cm}<l<25\text{cm}$. The atomic oxygen and nitrogen oxide concentrations prove to be less homogeneous than with the tantalum electrodes. The molecular oxygen content in plasma rises monotonically from the cathode to the anode. Significant re-formation of CO_2 near the platinum electrode can be explained by a catalytic action of platinum on the surface recombination reaction $CO + O \dashrightarrow CO_2$. By so doing, the elemination of atomic oxygen is mainly due to O atom capture by platinum and subsequent reaction with CO molecules rather than due to the $O + O \dashrightarrow O_2$ recombination. Observed concentration correlations for O and NO in both (a) and (b) cases indicate seemingly that the NO is formed from reactions of oxygen atoms with nitrogen molecules. Using a platinum cathode results in a greater in absolute value and opposite in sign gradient of CO_2 concentration in the discharge compared to the tantalum electrodes. This can be negative for sealed CO_2 laser operation. It should be noted, however, that the region of inhomogeneity is relatively small in our case and is of ~ 10 cm so that the removal of the electrodes from the optical axis would eliminate this effect. The characteristic size (l^*) of inhomogeneity is determined by the relation between the CO_2 dissociation (K_D) and diffusion ($D/l^{*2} \sim K_D$) rates. At $l > l^*$ the CO_2 dissociation degree in the positive column is the same for tubes with tantalum and platinum electrodes. If a platinum electrode is used as the anode the component distribution in the CO_2-N_2-He discharge is identical to that shown in Fig. 1a. This is because platinum catalyzes CO oxidation to CO_2 only when heated (4). The positive role of platinum electrodes for increasing the operation time without gas renewal in sealed lasers is thus associated with some increase of CO_2 concentration in the discharge volume (2, 5) The CO_2 concentration after switching off the discharge in the tube with a tantalum cathode is detected to be $\sim 40\%$ with respect to the starting CO_2 concentration. With a platinum cathode this ratio is of $\sim 60\%$. For the CO-He-O_2 discharge with a tantalum cathode, the dependences observed were similar to those in CO_2 mixture: CO_2 decomposition and CO re-formation near the cathode as well as atomic oxygen elimination and molecular oxygen formation.

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