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ON THE EXCITATION OF BALMER LINES IN Ar/SiH_4, Ar/H_2, $Ar/H_2/SiH_4$ CASCADED ARC EXPANSION PLASMAS

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Cascaded arc free expanding plasmas have shown good results in obtaining silicon based (a-Si:H) films at high deposition rates [1]. The mechanism of deposition is not yet understood. Therefore spectral studies are important because they can give information on the processes taking place in the plasma and on the surface. Also they can be used to develop methods to monitor the deposition process.

The experimental set-up consists of a cascaded arc plasma source and a spectral measuring system. The thermal plasma generated in the arc ($T = 1$ eV, $p = 0.5$ bar) expands supersonically and afterwards subsonically into a vacuum vessel maintained at low pressure ($p = 0.1 - 1$ mbar). The discharge is sustained in Ar, and H_2 is added in the middle part of the arc column. SiH_4 is admixed in the vacuum vessel in the early stage of the expansion. Spectra in the spectral range 3500-7500 Åhave been recorded at 32 cm distance from the nozzle exit just in front (1 cm distance) of the sample holder. The spectra presented in fig. 1 have been recorded for the settings: $I = 75$ A, $p = 0.2$ mbar and flow values A) Ar/H_2 (scc/s) = 60/10, B) $Ar/H_2/SiH_4$ (scc/s) = 60/10/0.5, C) Ar/SiH_4 (scc/s) = 60/0.5.

As shown in fig. 1 a low emission intensity results from feeeding the hydrogen in the arc (case A and B) and a high emission intensity if no hydrogen is fed in the arc (case C). The effect of adding hydrogen in the arc channel is known. For H_2 percentages above 10%, the ionization is transferred from Ar ions to H ions [2] and the chemical energy is carried out from arc by H^+ ions. However, as was shown by De Graaf et al. [3], these hydrogen ions are quickly destroyed by a chain of charge exchange with rovibrational excited molecules contained in the recirculating flow and a subsequent dissociative recombination of the formed molecular ion. This results in a lower excitation of the hydrogen Balmer lines in cases A and B. Consequently the chemical energy cannot be carried over long distances and the emission will be low. The presence of high quantum number Balmer lines encountered in the case of Ar/H_2 plasma is caused by the residual three particle recombination process of hydrogen ions leaving the arc ($n_e \approx 10^{17}$ m^{-3}). Lower levels could be specifically populated by the described process [3]. The molecular Fulcher α spectrum is absent showing there are no specific mechanisms able to populate the upper electronic state of H_2.

In the dissociation of SiH_4 by means of charge exchange with Ar^+ and subsequent dissociative recombination of the formed molecular ion, the Balmer series can not be excited since the chemical energy contained in the reaction is insufficient. As $T_e \approx 0.2$ eV and $n_e \approx 10^{18}$ m^{-3} [4], the relatively large emission in case C is again explained by the charge exchange of the Ar^+ ions left from the arc with recirculating rovibrational excited molecules and subsequent dissociative recombination of the molecular ion.

The absence of emission from high levels in the case of $Ar/H_2/SiH_4$ plasma suggests that there is a low remaining content of H^+ ions which we assumed to be essential in producing high level excited Balmer lines. From probe measurements it is known that the electron density in this plasma is approximately an order of magnitude lower than in case C ($n_e \approx 10^{17}$ m^{-3}) [5]. If the Balmer line excitation is totally due to three particle recombination, the

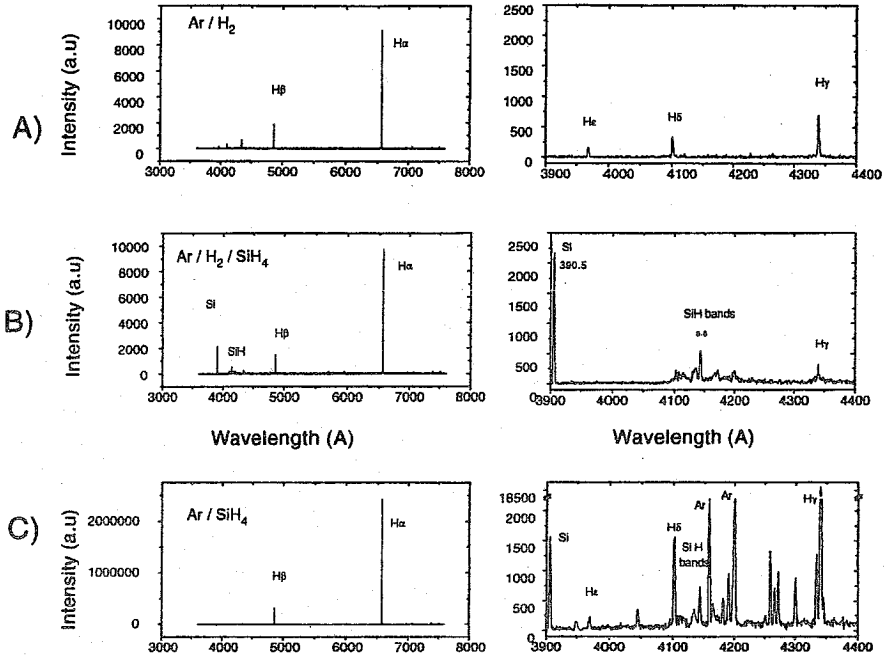

Figure 1: Spectra measured for different plasma compositions at 32 cm from the exit of the arc. left: global spectral range 3500-7500 Å; right: the SiH spectral range

dependence on n_e is cubic. Therefore the emission of the higher Balmer lines disappears in case B compared to case C. Since the emission of H_α and H_β is only slightly affected, this is another indication that also in case B, H_α and H_β is mainly due to recirculating rovibrational excited molecules.

References:

[1] R.J. Severens, M.C.M. van de Sanden, S. Brussaard, M. Schaepkens, G.J. Meeusen and D.C. Schram, see also this conference

[2] D.C. Schram et al., in Microwave Discharges: Fundamentals and Applications edited by C.M.Ferreira and M.Moisan, Plenum Press, New York,1993,page 247

[3] M.J. de Graaf, R.J. Severens, R.P. Dahiya, M.C.M. van de Sanden, D.C.Schram, Phys.Rev. E **48**, 2098 (1993)

[4] G.J. Meeusen, E.A. Ershov-Pavlov, R.F.G. Meulenbroeks, M.C.M. van de Sanden and D.C. Schram, J. Appl. Phys. **71** 4156 (1992)

[5] G.J. Meeusen, R.P. Dahiya, M.C.M. van de Sanden, G. Dinescu, R.F.G. Meulenbroeks, Z. Qing and D.C. Schram, to be published