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CHEMICAL EFFECTS ON SECONDARY PHOTON AND ION EMISSION OF ION
BOMBARDED BERYLLIUM, CARBON AND BORON CARBIDE SURFACES

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Chemical Effects on Secondary Photon and Ion Emission of Ion Bombarded Beryllium, Carbon and Boron Carbide Surfaces*

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Beryllium metal has been proposed as a low-Z material for a first-wall coating or liner in tokamak reactor vacuum vessel applications. In this connection, the effects of ion bombardment on the impurity release and erosion properties of beryllium need to be ascertained. The present work has focussed on the effects of oxygen and nitrogen bombardment on the secondary photon and secondary ion emission properties of beryllium. The most significant finding is that both the secondary photon and ion emission are strongly enhanced as a result of oxygen and nitrogen bombardment. This finding is of potential importance to impurity control and transport problems associated with fusion reactor applications of beryllium.

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Secondary Photon Emission

The secondary photon emission from beryllium was measured as a function of incident ion energy from 200 eV to 15 keV and for current densities varying from 10 to 800 $\mu\text{A}/\text{cm}^2$ for Kr^+ , Ar^+ , Ne^+ , He^+ , O_2^+ , and N_2^+ . By monitoring the secondary photon emission yield of four of the most intense Be(I) lines ($2s^2$ - $2s2p$, 234.86 nm; $2s2p$ - $2s3d$, 249.47 nm; $2s2p$ - $2p^2$, 265.06 nm; $2s2p$ - $2s3s$, 352.11 nm) and one Be(II) line ($2s$ - $2p$, 313.07 nm) it was possible to gain insight into the excitation coefficients and excitation mechanisms leading to secondary photon emission from excited sputtered beryllium. It should be stressed that reproducible results could be achieved only after extensive sputter-ion cleaning of the beryllium target surface, with careful attention given to control of residual gas impurities in the target vacuum chamber. Partial pressures of less than 10^{-9} torr of H_2O and O_2 were maintained during bombardment in order to prevent formation of an oxide layer which had been shown strongly to effect the results. Shown in Figure 1 is the energy dependence for various incident ions on the Be(II) emission yield (peak yield divided by the ion beam current density). The results for O_2^+ , and N_2^+ have been plotted as the mono-ion equivalent obtained by halving

the molecular ion incident energy and doubling the current density. In Figure 1 it is apparent that the secondary photon emission does not scale as the sputtering yields for the various incident ions. Based on the theoretical sputtering yields [1,2] the relative yields should be $Kr^+ > Ar^+ > Ne^+ > O^+ > N^+ > He^+$ which is not observed. The emission yield for the noble gas ions at 3 keV are observed to be in the order $Ne^+ > Ar^+ > Kr^+ > He^+$. Consideration of the effects of non-radiative de-excitation mechanisms such as resonance neutralization or Auger de-excitation of excited ions at the surface-vacuum interface [3] is insufficient to rationalize the observations. It appears that excitation mechanisms also need to be considered since it was found that the results depend on the nature of the bombarding ion as well as on the target. The large yield enhancement with O_2^+ and N_2^+ indicates that a "chemical" effect is operative with these ions. The chemically reactive ions alter the target surface and near-surface electronic states by changing the chemical composition which in turn appears to alter the excitation and de-excitation cross-sections. The four Be(I) emission lines displayed behavior similar to that observed with Be(II) for the inert-gas ions as well as the "chemical" effects due to O_2^+ and N_2^+ .

Enhancement of the secondary photon emission for all the Be lines studied was also observed to occur when the partial pressure of O_2 and N_2 was increased in the target chamber during inert-gas ion bombardment. The magnitude and temporal behavior of the pressure dependent enhancement was a function of the mass, energy and current density of the inert-gas ion.

The current density dependence of the secondary photon emission yield at fixed primary energy for each of the different incident ions was also measured. The yield was proportional to J (current density, $\mu A/cm^2$) for the inert-gas incident ions; and proportional to J^a with a equal to 0.7 to 0.8 for O_2^+ and N_2^+ .

Only emission from excited boron neutrals was observed during ion bombardment of B_4C ($2s^2 2p-2s^2 3s$, 249.74 nm and $2s^2 2p-2s 2p^2$, 208.93 nm). Very weak secondary photon emission during 15 keV Ar^+ bombardment of graphite was observed at 247.86 nm ($^1S-^1D$) and 193.09 nm ($^1D-^1P$) as well as emission from excited C_2 molecules over the region 400-520 nm.

Secondary Ion Emission

A corresponding study of the secondary ion emission of Be^+ for different incident ions as a function of energy was also conducted. The results are shown in Figure 2 for a fixed energy window of 10-16 eV on the mass analyzer. A "chemical" enhancement of the secondary Be^+ ion current is also observed

to occur for the chemically reactive O_2^+ and N_2^+ . Variation of the secondary Be^+ yield from that expected on the basis of inert-gas sputtering yields is similarly detected. The results on secondary ion emission from Be surfaces indicate a commonality with the excitation and de-excitation processes involved in the secondary photon emission discussed above.

References

1. P. Sigmund, Phys. Rev., 189 (1969) 383.
2. W. M. Stacey, Jr., D. L. Smith, J. N. Brooks, P. J. Bertoncini and D. A. Ehst, Impurity Control in Tokamak Reactors, ANL/FPP/TM-91, Argonne National Laboratory (1977).
3. W. F. van der Weg and P. K. Rol, Nucl. Instr. Meth. 38 (1965) 274.

Figure Captions

Fig. 1. Energy dependence for different incident ions of the secondary photon emission yield of Be(II) at 313.07 nm. Data for all incident ions was taken at a current density of $125 \mu\text{A}/\text{cm}^2$ (6.25 μA current). The data for O_2^+ and N_2^+ is shown as the mono-ion equivalent.

Fig. 2. Energy dependence of Be^+ secondary ion yield for different incident ions. Data for all incident ions was taken at a current density of $88 \mu\text{A}/\text{cm}^2$ (4.4 μA current). The data for O_2^+ and N_2^+ is shown as the mono-ion equivalent.

Fig. 1

Fig. 2