ABSTRACT

We discuss the modification by ion bombardment of the surfaces of icy objects in the Saturian and Jovian systems. Chemical changes in ices are induced by breaking of bonds and by implantation of incident ions. Long-term irradiation by fast ions produces physical changes such as increasing the surface reflectivity and ability to scatter light. On large satellites molecules which are ejected by ion bombardment are redistributed across the surfaces of large satellites. For small satellites and ring particles bombarded by ions, such as those of Saturn, most or all of the sputtered material is lost to space, forming a neutral torus in the locale of the satellite orbits and rings and supplying ions to the magnetosphere. Noting the existence of such a torus the sputter erosion and possible stabilization of the E-ring of Saturn is discussed.
Pioneer and Voyager spacecraft measurements showed that the magnetospheres of Saturn and Jupiter confine high fluxes of energetic ions (1,2). These ions continuously bombard the surfaces of the icy satellites and rings. In this paper we briefly explore some of the changes induced in the ices and the effect of the bombardment on the composition of the magnetospheric plasma.

The magnetospheric plasma ions are arbitrarily divided by kinetic energy into two components: (a) an energetic keV to 100's of keV component of light ions, mostly protons, which are assumed to bombard the satellites nearly isotropically, (b) a component of slow and/or heavy ions having kinetic energies much less than the energy associated with the rotation of the magnetic field and having gyroradii much less than the satellite radii. This component can be thought of as co-rotating with the magnetic field lines and preferentially bombards the trailing hemisphere of the satellites. Small ring particles can be thought of as being isotropically bombarded by all of the ions.

Because of this bombardment the icy surfaces observed in the Jovian and Saturnian systems are considerably modified from that of a pristine, freshly deposited ice. Ion bombardment results in the modification of the surface microscopic roughness (3), sputtering (or ejection) of material from the satellite (4) and redistribution across the surface (5), changes in the surface concentration of impurities (3), and modification of the composition by inducing chemical reactions (6-10) and by ion implantation (11,12). That the albedo of the surface is affected by such exogenic processes is indicated by a number of observations. Photographs of Ganymede and Europa show leading/trailing asymmetries and visual differences from equators to poles (13). Lane et al. (11) have found differences in the U.V. from the leading to the trailing hemisphere of Europa and Nelson et al. (14) have shown that systematic leading-trailing (as well as pole to equator) asymmetries in the ratio of U.V. to violet reflectance spectra exist for Europa and Ganymede. Initially it was uncertain whether, in fact, the ions could reach the satellite surfaces if these objects had small atmospheres or magnetospheres. The above observations, however, provide evidence that such bombardment does occur. In the following we review and discuss, briefly, a few of the effects produced by ion bombardment of the satellites of Jupiter and Saturn and the E-ring of Saturn. We first consider the chemical and physical changes induced in the surface layers and then the loss of surface (sputter ejection) and redistribution of this material.