Low Temperature Cathodoluminescence of Space Observatory Materials

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Recommended Citation  
Evans Jensen, Amberly; Wilson, Gregory; Dekany, Justin; and Dennison, JR, "Low Temperature Cathodoluminescence of Space Observatory Materials" (2012). 12th Spacecraft Charging Technology Conference. Presentations. Paper 50.  
https://digitalcommons.usu.edu/mp_presentations/50
**Abstract**

Disordered SiO$_2$, is commonly used for optical instrumentation and coatings. In space telescope applications, these materials can be exposed to low temperatures (particularly for IR telescopes) and simultaneous electron fluxes from the space plasma environment. During recent charging tests of this dielectric material, a discernable glow was detected emanating from the surface of the SiO$_2$, indicating that the incident electron beam induced luminescence. Instrumentation includes picoammeters, Pearson coils, and a NMR camera for optical measurements. From our experimental results in conjunction with literature references, the specific structural defects in SiO$_2$ responsible for distinct features in the cathodoluminescence spectra can be identified.

**Experimentation**

In basic band theory, the energy levels of individual atoms coalesce, forming a continuum of energy gaps. As the number of atoms increases, so do the number of new energy levels, eventually creating a continuum, or band, of energy levels for the electrons in our new structure to fill. Within a molecular or crystalline structure, many energy bands are formed and are filled, starting at the band of lowest energy. The extent to which these bands are filled is how solids are classified as conductors, semiconductors and insulators.

The Fermi energy of a material is the energy of the highest filled state at absolute zero; the Fermi level, $E_F$, is the (weakly) temperature dependent chemical potential defined as the energy for 50% probability filling a state. As in our experiments, electrons are added to the material by, say, electron bombardment, these new electrons will start to fill up higher energy levels, thus creating an effective Fermi level, $E_F^{\text{eff}}$, which can be thought of as a change in temperature dependent chemical potential.

Conductors are materials with partially filled energy bands, giving the electrons that occupy band high mobility, allowing electrons to move freely. Insulators have a fully filled valence band and a large gap to the conduction band, such that even with large amounts of thermal energy valence electrons have an extremely low probability of being thermally excited into the conduction band. This small mobility makes these materials electrically insulating. For intrinsic insulators and semiconductors with no defect states, the Fermi energy is at the middle of the band gap. Semiconductors have two bands that are separated by a small amount of energy so that, with sufficient thermal energy, electrons in the valence band have a small but significant probability of excitation into the higher bands, therefore leading to moderate conductivity.

**Future Work and Acknowledgements**

Right now, our model is only a qualitative one used to illustrate the behavior of our SiO$_2$ thin films. In the very near future, this model will be a quantitative one. Its validity will also be put to the test as experiments are extended to lower temperatures, down to 4K.

Funding for this project was from NASA Goddard Space Flight Center.