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Monolithic Aluminum Nitride High Gradient Vacuum Insulators

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In the design of pulsed relativistic accelerators, high power electrical pulses are generated in a volume that is filled with either high pressure gas or an oil to manage the high electric fields. However, the beam generating diode must operate in vacuum. The two sections, then, require an insulating barrier between them which is subject to very high electric fields. The vast majority of interface insulators are made from polymers such as acrylics, polystyrenes, and epoxies because they are easy to machine and have well characterized high voltage performance. These materials create problems in achieving high-quality vacuum due to outgassing and the temperature limitations that prevent baking. Polymers also limit the ability to operate at high repetition rates due to poor thermal conductivity and low maximum temperature limits. Ceramic vacuum insulators are widely used in construction of conventional vacuum electronic devices, but have not found extensive use in relativistic pulsed accelerators. Aluminum nitride (AlN) is a covalently-bonded unique dielectric ceramic that combines high thermal conductivity with high bulk breakdown strength and resistivity. High gradient insulators (HGIs) are electrical insulating structures for vacuum applications composed of thin alternating layers of metal and dielectric. The HGI was originally conceived in the early 1980s and follows from the observation that the threshold electric field strength for surface flashover increases with decreased insulator length. Thus, by breaking up the total length into small segments, the breakdown mechanism scales with the shorter length, resulting in an overall increase in the vacuum flashover voltage compared to conventional insulators of the same length. The University of New Mexico has partnered with Sienna Technologies, a US company that specializes in the fabrication of high technology ceramic materials, to develop and test AlN high-gradient insulators for application in high power pulsed vacuum electronic devices.

Authors: LEHR, Jane (University of New Mexico); POUNCEY, Jon (University on New Mexico); Dr SAVRUN, Ender (Sienna Technologies Inc)

Presenter: POUNCEY, Jon (University on New Mexico)

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