

# CRYOGENIC OPERATION OF SILICON POWER DEVICES

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Ranbir Singh  
B. Jayant Baliga

Power Electronics and Power Systems Series

# Cryogenic Operation Of Silicon Power Devices

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## **Cryogenic Operation Of Silicon Power Devices:**

**Cryogenic Operation of Silicon Power Devices** Ranbir Singh, B. Jayant Baliga, 2012-12-06 The advent of low temperature superconductors in the early 1960 s converted what had been a laboratory curiosity with very limited possibilities to a practical means of fabricating electrical components and devices with lossless conductors Using liquid helium as a coolant the successful construction and operation of high field strength magnet systems alternators motors and transmission lines was announced These developments ushered in the era of what may be termed cryogenic power engineering and a decade later successful operating systems could be found such as the 5 T saddle magnet designed and built in the United States by the Argonne National Laboratory and installed on an experimental power generating facility at the High Temperature Institute in Moscow Russia The field of digital computers provided an incentive of a quite different kind to operate at cryogenic temperatures In this case the objective was to obtain higher switching speeds than are possible at ambient temperatures with the critical issue being the operating characteristics of semiconductor switches under cryogenic conditions By 1980 cryogenic electronics was established as another branch of electric engineering

**Advances in Cryogenic Engineering** Quan-Sheng Shu, Peter Kittel, David Glaister, John Hull, Bill Burt, Al Zeller, John Zbasnik, Vitalij Pecharsky, Steven W. Van Sciver, Ray Radebaugh, Michael DiPirro, J. Patrick Kelley, Klaus D. Timmerhaus, Jay Theilacker, Charles Reece, 2013-12-19 In recent years the technology of cryogenic comminution has been widely applied in the field of chemical engineering food making medicine production and particularly in recycling of waste materials Because of the increasing pollution of waste tires and the shortage of raw rubber resource the recycling process for waste rubber products has become important and commercially viable This technology has shown a great number of advantages such as causing no environmental pollution requiring low energy consumption and producing high quality products Hence the normal crusher which was used to reclaim materials such as waste tires nylon plastic and many polymer materials at atmospheric 12 temperature is being replaced by a cryogenic crusher In the cryogenic crusher the property of the milled material is usually very sensitive to temperature change When a crusher is in operation it will generate a great deal of heat that causes the material temperature increased Once the temperature increases over the vitrification temperature the material property will change and lose the brittle behavior causing the energy consumption to rise sharply Consequently the comminution process cannot be continued Therefore it is believed that the cryogenic crusher is the most critical component in the cryogenic comminution system The research on the temperature increase and energy consumption in the cryogenic crusher is not only to reduce the energy consumption of the crusher but also to reduce the energy consumption of the cryogenic system

**Electrified Aircraft Propulsion** Kiruba Haran, Nateri Madavan, Tim C. O'Connell, 2022-05-26 What are the benefits of electrified propulsion for large aircraft What technology advancements are required to realize these benefits How can the aerospace industry transition from today's technologies to state of the art electrified systems Learn the answers with this

multidisciplinary text combining expertise from leading researchers in electrified aircraft propulsion The book includes broad coverage of electrification technologies spanning power systems and power electronics materials science superconductivity and cryogenics thermal management battery chemistry system design and system optimization and a clear cut road map identifying remaining gaps between the current state of the art and future performance technologies Providing expert guidance on areas for future research and investment and an ideal introduction to cutting edge advances and outstanding challenges in large electric aircraft design this is a perfect resource for graduate students researchers electrical and aeronautical engineers policymakers and management professionals interested in next generation commercial flight technologies

*The IGBT Device* B. Jayant Baliga, 2015-03-06 The IGBT device has proved to be a highly important Power Semiconductor providing the basis for adjustable speed motor drives used in air conditioning and refrigeration and railway locomotives electronic ignition systems for gasolinepowered motor vehicles and energy saving compact fluorescent light bulbs Recent applications include plasma displays flat screen TVs and electric power transmission systems alternative energy systems and energy storage This book is the first available to cover the applications of the IGBT and provide the essential information needed by applications engineers to design new products using the device in sectors including consumer industrial lighting transportation medical and renewable energy The author B Jayant Baliga invented the IGBT in 1980 while working for GE His book will unlock IGBT for a new generation of engineering applications making it essential reading for a wide audience of electrical engineers and design engineers as well as an important publication for semiconductor specialists Essential design information for applications engineers utilizing IGBTs in the consumer industrial lighting transportation medical and renewable energy sectors Readers will learn the methodology for the design of IGBT chips including edge terminations cell topologies gate layouts and integrated current sensors The first book to cover applications of the IGBT a device manufactured around the world by more than a dozen companies with sales exceeding 5 Billion written by the inventor of the device

Low Temperature Electronics and Low Temperature Cofired Ceramic Based Electronic Devices Electrochemical Society. Meeting, 2004 **Proceedings of the ... International Symposium on Power Semiconductor Devices and ICs**, 2003 *Utilising Power Devices Below 100 K to Achieve Ultra-low Power Losses* Kenneth Kin Leong, 2011

One of the main trend in the development of high power electric machines motors generators is to replace the magnetic components with superconducting wires this inevitably leads to a critical requirement from the industry Convert team to operate power devices at cryogenic temperatures However the current understanding of the behaviour power devices at cryogenic temperatures is limited especially below the liquid nitrogen temperature of 77 K This is a problem since most of the superconducting wires operate at temperatures below 77 K Furthermore it is uncertain which device type is better if at all suited to cryogenic operation In order to answer this a thorough analysis of the known cryogenic behaviour of all the generic power devices was performed including the physical behaviour of silicon at cryogenic temperatures It is concluded

that the power MOSFET is the best likely candidate for cryogenic operation To understand the cryogenic behaviour of silicon power MOSFETs especially between the temperatures of 20 K and 100 K a cryogenic measurement system was built to characterise different types of power MOSFETs All the measured power MOSFETs exhibited large improvement in on state resistance down to 50 K and non linear degradation of breakdown voltages with lower temperatures Various behaviour was observed below 50 K including carrier freeze out electric field dependent ionisation of free charge carriers and large variations in on state resistance between identical devices Several power Schottky diodes were also characterised and all exhibited merged PiN Schottky diode behaviour at cryogenic temperatures Non silicon devices such as silicon carbide power MOSFETs and gallium nitride HEMTs were also measured Silicon carbide exhibited no improvements at cryogenic temperatures whereas gallium nitride HEMTs may prove to be the best power device to be utilised in future cryogenic applications Since unusual behaviour was observed in power MOSFETs below 50 K an attempt was made to explain these phenomena using theoretical equations of semiconductor physics and analytical models of power MOSFETs The author suggested that careful control of the dopant concentration at the accumulation region below the oxide gate is required to improve the power MOSFET operations below 50 K Moreover the super junction power MOSFETs could be optimised for better cryogenic operation It is the intention of this work to demonstrate the benefits of power MOSFET cryogenic operation in a realistic industrial application A demonstration model was designed and simulated this circuit uses a back to back power MOSFETs configuration to control the freewheeling current flowing through a high temperature superconducting coil The electrical and thermal design of the model has been described simulated and presented in this work

**Device and Circuit Cryogenic Operation for Low Temperature Electronics** Francis Balestra, Gérard Ghibaudo, 2001-05-31 Device and Circuit Cryogenic Operation for Low Temperature Electronics is a first in reviewing the performance and physical mechanisms of advanced devices and circuits at cryogenic temperatures that can be used for many applications The first two chapters cover bulk silicon and SOI MOSFETs The electronic transport in the inversion layer the influence of impurity freeze out the special electrical properties of SOI structures the device reliability and the interest of a low temperature operation for the ultimate integration of silicon down to nanometer dimensions are described The next two chapters deal with Silicon Germanium and III V Heterojunction Bipolar Transistors as well as III V High Electron Mobility Transistors HEMT The basic physics of the SiGe HBT and its unique cryogenic capabilities the optimization of such bipolar devices and the performance of SiGe HBT BiCMOS technology at liquid nitrogen temperature are examined The physical effects in III V semiconductors at low temperature the HEMT and HBT static high frequency and noise properties and the comparison of various cooled III V devices are also addressed The next chapter treats quantum effect devices made of silicon materials The major quantum effects at low temperature quantum wires quantum dots as well as single electron devices and applications are investigated The last chapter overviews the performances of cryogenic circuits and their applications The low temperature properties and

performance of inverters multipliers adders operational amplifiers memories microprocessors imaging devices circuits and systems sensors and read out circuits are analyzed Device and Circuit Cryogenic Operation for Low Temperature Electronics is useful for researchers engineers Ph D and M S students working in the field of advanced electron devices and circuits new semiconductor materials and low temperature electronics and physics     Journal de physique ,2002     **ISPSD '92** IEEE Electron Devices Society,1992     *Cryogenic Operation of Power Semiconductor Devices* Ranbir Singh,1997     **The Cumulative Book Index** ,1999     *Bulletin de L'Institut International Du Froid* ,2005     Cumulated Index to the Books ,1999     The British National Bibliography Arthur James Wells,1999     **Subject Guide to Books in Print** ,1991     Photodetectors ,1998     Soviet Physics ,1985     Optoelectronic Interconnects ,1995     **Books In Print 2004-2005** Ed Bowker Staff,Staff Bowker, Ed,2004

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