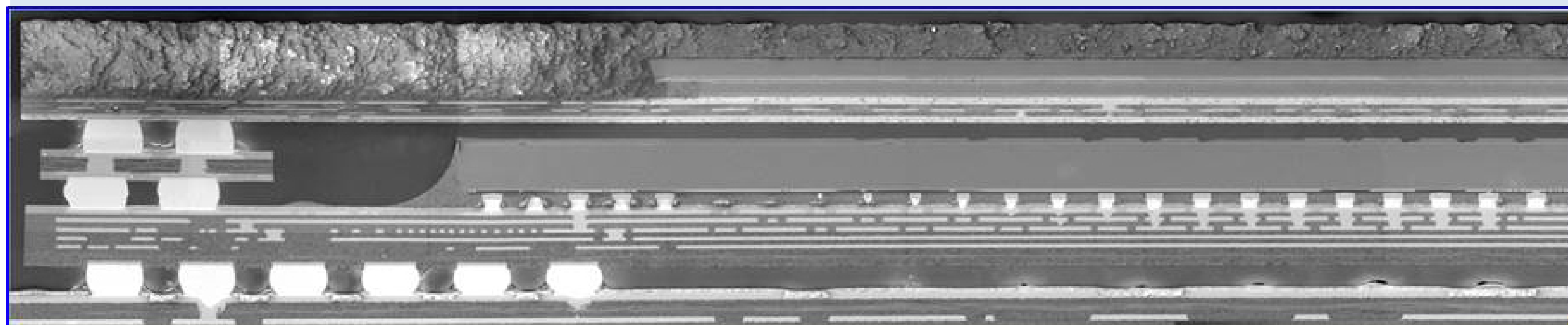
TECHNOLOGY REPORT

Current Developments in 3D Packaging With Focus on Embedded Substrate Technologies

PSMA 3D Power Packaging Phase II
A Special Project of the
PSMA Packaging Committee

March 2015



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Technology Report

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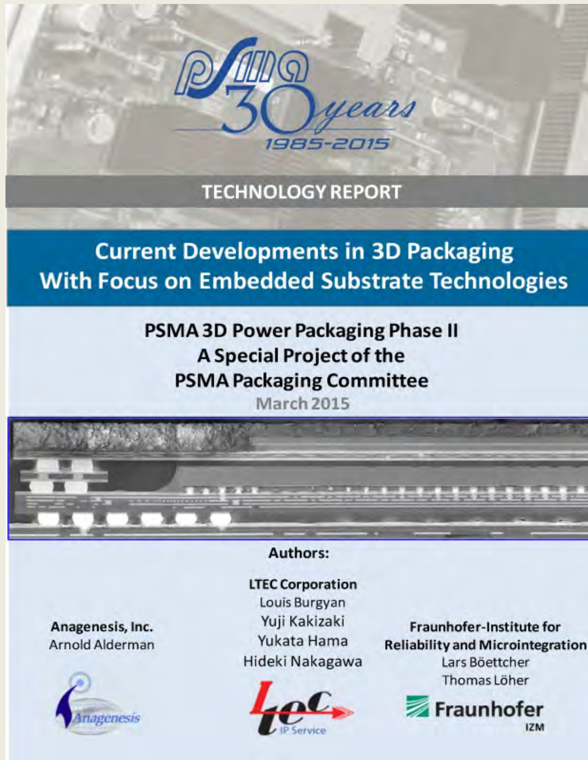
CURRENT DEVELOPMENTS IN 3D PACKAGING WITH FOCUS ON EMBEDDED SUBSTRATE TECHNOLOGIES



March 15, 2015. LTEC Corporation, a Lead-Contractor for the Power Sources Manufacturers Association (PSMA), is pleased to offer this comprehensive technology report on embedded substrate, 3D packaging, and related technologies, prepared for the PSMA. This 340 page report was produced under contract by LTEC Corporation with contributing sub-contracting teams from Anagenesis Inc. (US) and the Fraunhofer Institute for Reliability and Microintegration, in Berlin, Germany.

The report seeks to assist executives and managers in their own analysis of how currently available packaging and embedding technologies could be best used for the creation of advanced high efficiency and high power-density power electronic products. The key findings in this report are summarized at the end of each of the ten chapters, and in the conclusion section at the end of the report. Strategic observations and implications based on those findings are also included.

This report is a summation of learnings from over one thousand scientific papers, magazine articles, conference proceedings, and news releases. The report has 394 publications cited and 174 web links provided. During the year of 2014, a total of ten conferences and workshops were attended, and one additional set of conference papers was purchased and studied. This work also includes technology roadmaps, technology influence maps, high-level patent landscape analysis, and some highlights of reverse engineering work.

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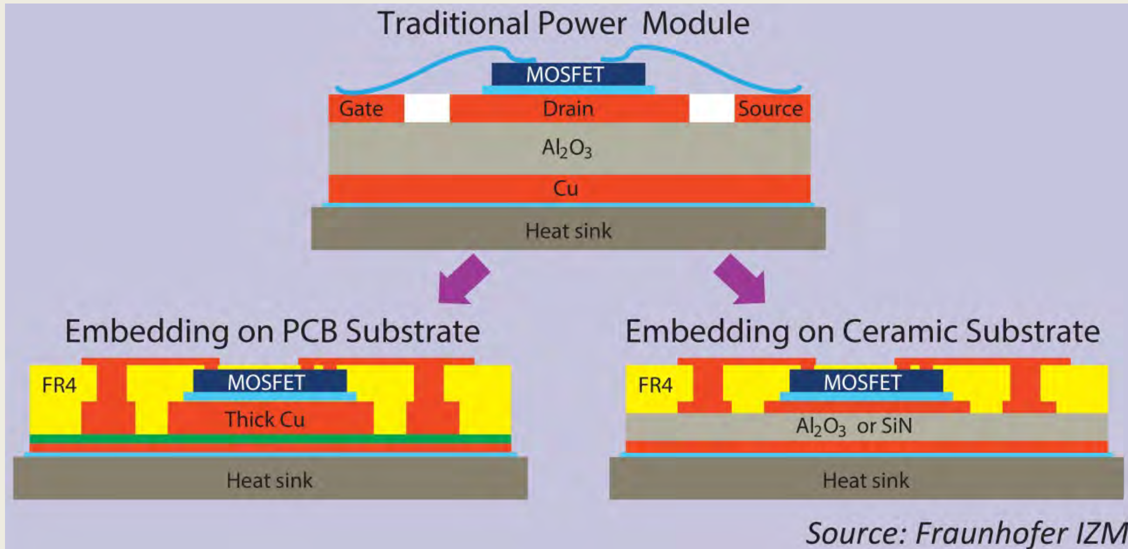
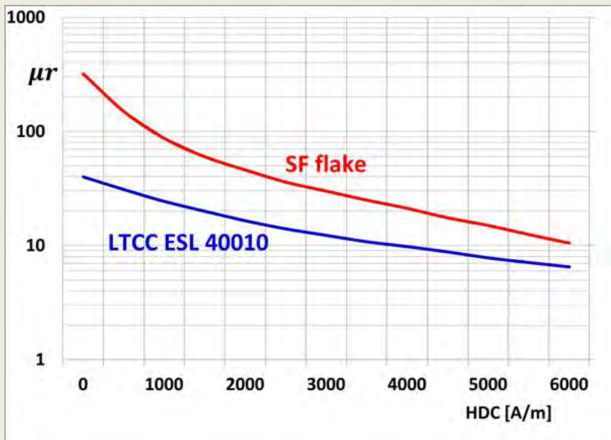
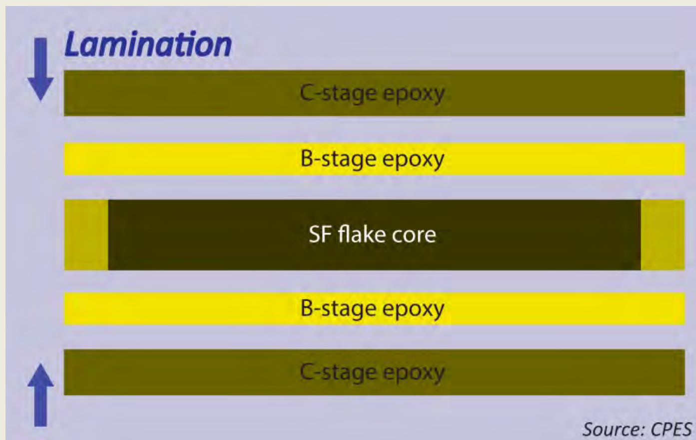
Selected Highlights

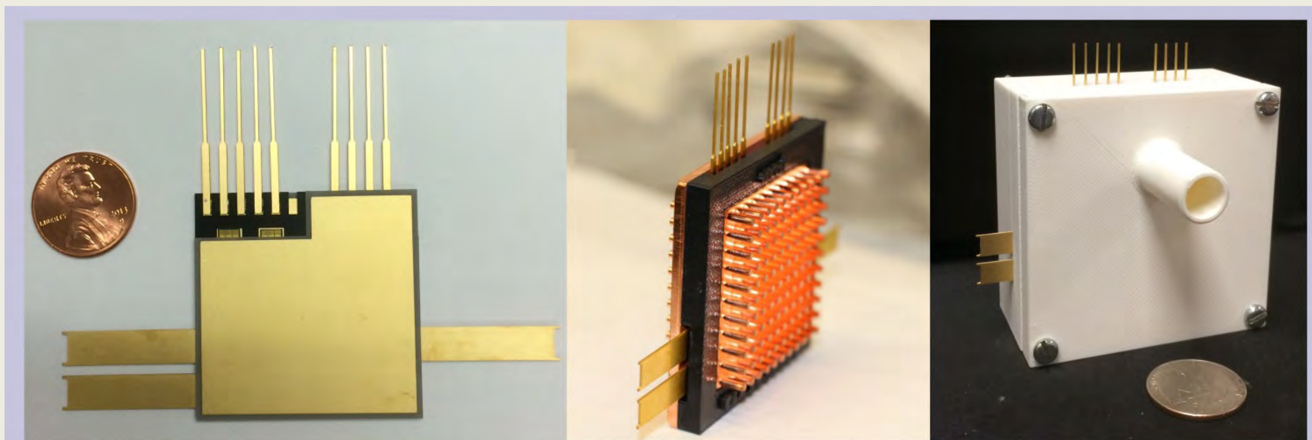


Embedded alternatives to traditional high power module implementation

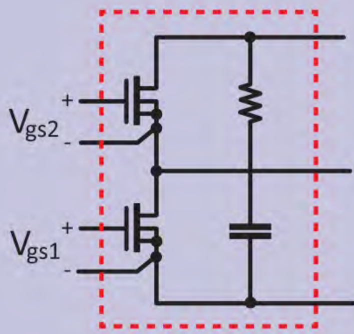


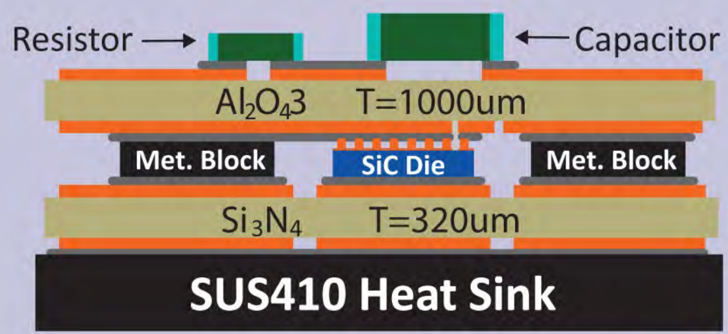


(a) Alloy flake magnetic material vs. LTCC ferrite **(b) Embedding alloy flake material**

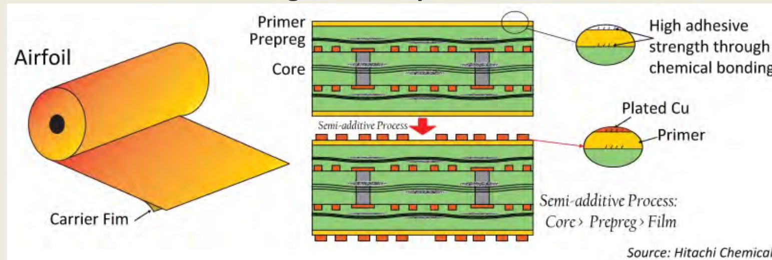


Advanced highly integrated 1200V 100A liquid-cooled power module

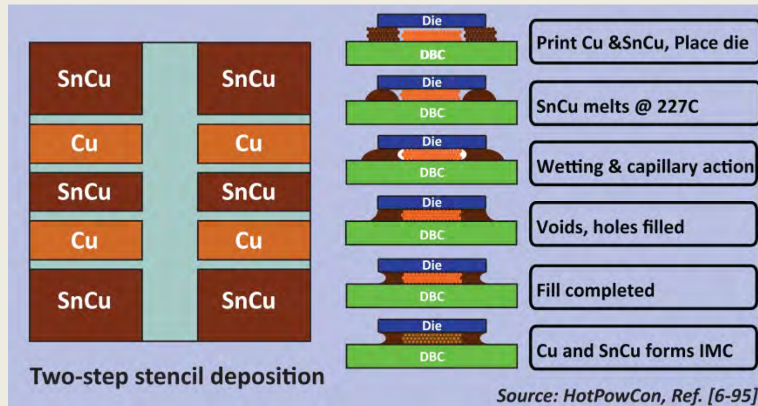




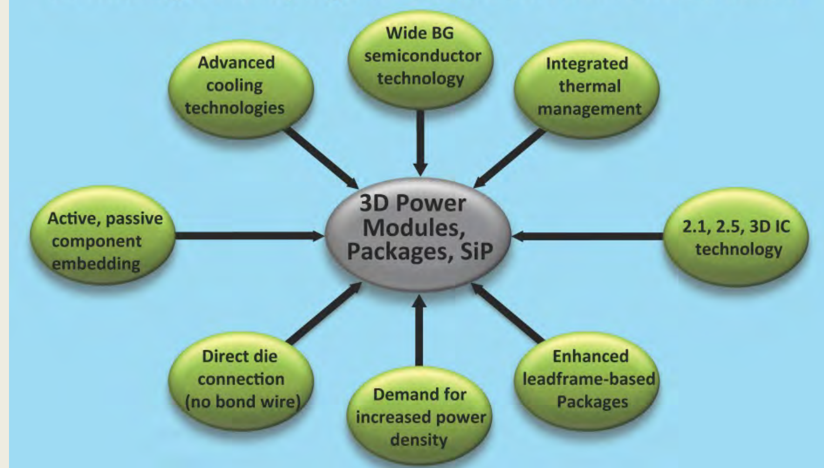
Integrated SiC power module



Hitachi Chemical's advanced low CTE substrate material



A promising high temperature die/component attach method



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Power Sources Manufacturers Association Publications Available for Purchase from LTEC Corporation

THE POWER TECHNOLOGY ROADMAP REPORT (2015): This Ninth Edition Report includes presentations and discussions from many of the industry's most influential members representing end-users, power supply manufacturers, component suppliers, consultants, and academia. This roadmap report goal is to provide an outlook on technology trends in power conversion through the year 2019. The technology trend analysis and the roadmap are provided for the following specific product families expected to be the areas of largest market growth: AC-DC front-end power supplies; External AC-DC power supplies; Isolated DC-DC converters; and Non-isolated DC-DC converters. As was provided in the 2013 report, a Flash Drive is included with this publication that includes all of the presentations that were an integral part of the information gathering process and include the PowerPoint charts together with the audio and the Q/A discussions.

TECHNOLOGY REPORT – CURRENT DEVELOPMENTS IN 3D POWER PACKAGING WITH FOCUS ON EMBEDDED SUBSTRATE TECHNOLOGIES (2015): This report is the Phase 2 report on 3D packaging of power sources and is a follow up to the previous report published by the PSMA Packaging Committee. The report begins with a discussion of PCB embedding technologies that are now in high volume production, and together with 3D packaging technology predominately provide a significant performance and size reduction enhancement opportunity rather than a means to reduce costs. Also presented is information on high temperature die and component attachment technologies that are evolving rapidly in the research labs. However, high power-density component embedding and 3D packaging of power semiconductors also have to overcome a 'thermal barrier" – since it is more challenging to remove heat generated within the body of a 3D integrated system than from a planar surface. To execute an embedded power design is very dependent on the availability of passive components optimized for PCB embedding, and the report includes some of the available sources. The report also includes the results of a worldwide literature search of R&D published by participating organizations. These technologies, combined with wide-bandgap semiconductor devices will literally re-vitalize the entire power electronics infrastructure block by block, module by module, for the twenty-first century.

POWER ELECTRONICS AND ELECTRICAL CHALLENGES FOR ENERGY EFFICIENT BUILDINGS (2014): The PSMA strives to bring awareness, education, and action to the subjects of energy efficiency and power electronics. In line with the previous workshops held in conjunction with the APEC Conference, PSMA partnered with the IEEE PELS society to hold this conference on the "Power Electronic and Electrical Challenges for Engineering Energy Efficient Buildings." Seventy percent of the global energy is consumed in commercial and residential buildings. Power electronics is a major component in the effort to efficiently utilize the energy consumed. Professor Philip Krein, of the University of Illinois Urbana, as Chair of the workshop, gathered seven experts to seed the workshop with a level of expertise that enabled the workshop participants to discuss topics ranging from planning large energy-efficient buildings, life cycle costing and analysis, to AC-DC nanogrids, DC nanogrids, energy monitoring, and an overview of two large-scale energy-efficient buildings at NREL and the University of Illinois.

TECHNOLOGY REPORT 3D POWER PACKAGING (2014): This report on 3D packaging of power sources is published by the PSMA Packaging Committee. The aim of the report is to review emerging 3D and other high density packaging trends and their possible application and impact on the electronic power conversion sector. The report posits that the challenge for the power packaging engineer is increasing. The well understood SMT device on PCB is now stretched to meet many emerging application requirements if current industry participants are to remain competitive. We believe a period of significant industry learning and investment in new packaging technologies is now required. The drivers for many of the required 3D packaging technologies have in many cases been in automotive and niche industrial areas, with

the consumer electronics industry also being an area of significant innovation in packaging in recent years. Many of these technologies are now entering mainstream power conversion deployments.

ARE YOU SMART ENOUGH FOR THE SMART GRID - A REPORT ON THE ENERGY EFFICIENCY WORKSHOP JOINTLY SPONSORED BY PSMA AND EPRI (2013): Topics range from explanation and definition of the grid and the smart grid drivers for change to management issues, communications, security concerns, technical challenges and solutions. This report is a benefit of membership in PSMA and is not available for sale to non-members. Contact power@psma.com for more information.

TRANSFORMERS FOR ELECTRONIC CIRCUITS – Second Edition Reprint (2011): This is a reprinted edition of one of the classic design texts on magnetics design! It is a complete, one-stop guide to transformer and inductor design and applications for everyone who designs, builds, or uses power magnetics components. Throughout this book, the author combines analysis and synthesis, and all theory is related to the solution of real-world problems. Sections of the text provide guidance in the use of transformers and inductors in power electronics and in digital and pulse circuits. Also included is design information about other forms of high-frequency magnetics such as transmission-line transformers, hybrid transformers, ferroresonant transformers, flyback converter magnetics and inductors used in switch mode power converter designs. Special attention is given in the book to the proper control of dielectric stress, and corona and thermal factors in high-voltage magnetics designs. Modeling methods for magnetic parts are also included and treated in some detail. This book is an essential reference book for any engineer involved in the design and development of modern-day magnetic components.

SOFT FERRITES – PROPERTIES AND APPLICATIONS – Second Edition Reprint (2010): This is the second in a series of classic magnetics texts offered to designers and students in the power electronics industry. The book was initially published in 1969 and was extensively revised by the author, E.C. Snelling, in 1988 to bring all eleven chapters in line with current design practices and applications of ferrite cores used in modern-day inductors and transformers. The aim of this unique 366-page reprint is to provide all the information on ferrite properties and wound-component design necessary for efficient applications of these materials. Data in the book is represented by means of extensive use of graphs and tables, and design procedures are supported by many working examples of inductors and transformers.

MODERN DC-TO-DC SWITCHMODE POWER CONVERTER CIRCUITS by Rudolf Severns and Ed Bloom - Reprint (2009): This book focuses on the fundamental behavior and characteristics of switch-mode power converters and on the relative merits of many popular topologies. The first 11 chapters present the basic theory of switchmode power converter circuits with minimal use of mathematics. Chapter 12 focuses on converter circuits with integrated magnetics and concludes with an extensive bibliography and helpful lists of suggested reading materials for reference and research purposes.

APPLICATIONS OF MAGNETISM by J. K. Watson - Reprint (2008): This classic book, written by one of the most respected teachers in the field of magnetics, makes the principles of applied magnetics accessible to the practicing electronics engineer. With emphasis on practical design, the text presents the relevant principles of physics, circuit analysis, simple models, and the calculations involved in designing a circuit or a magnetic device. Applications of magnetics, including those associated with power electronics circuits, are covered as well as reluctance modeling methods for transformers and inductors.

HANDBOOK OF STANDARDIZED TERMINOLOGY FOR THE POWER SOURCES INDUSTRY – 3rd Edition (2007): The publication has been completely revised and updated. In addition to definitions, there are eight appendices providing resource information on testing and standards agencies, world voltages and frequencies, and EMI and MIL specs. There is also valuable information on writing technical publications and guides for units, symbols, and style. A CD is included with this publication.

ELECTRONIC TRANSFORMERS AND CIRCUITS – Third Edition Reprint (2007): This is the third in a series of classic magnetics texts offered to designers and students in the power electronics industry. The book, authored by the late Rueben Lee and co-authored by Leo Wilson and Charles E. Carter was initially published by John Wiley and Sons in 1988, but has been out of print for several years. Lee's classic book is considered by many magnetics design specialists as a thoroughly practical book in designing many types of magnetics devices and their applications, including power and pulse transformers and inductive components.

UNITS, SYMBOLS, AND STYLE GUIDE FOR POWER ELECTRONICS DOCUMENTS (1998): This document is intended as a guide for writers of specifications, catalogs, application notes and correspondence in power electronics. It is derived from the current international standard, ANSI/IEEE Std 260.1-1993, used by the electronics industry world- wide when writing in English. It is printing in a one page (two sides) format, which is laminated and pre-punched for convenient filing in a notebook type binder. The Power Sources Manufacturers Association has prepared this guide in hope that it will lead to more uniform documentation and correspondence in the power electronics industry.

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Technology Report 3D Power Packaging (2014)	$150.00	$2,490.00
Are you smart enough for the Smart Grid - a Report on the Energy Efficiency Workshop Jointly Sponsored by PSMA and EPRI (2013)	Contact PSMA office	Not for sale
Transformers for Electronic Circuits – Second edition reprint (2011)	$55.00	$75.00
Soft Ferrites – Properties and Applications - second edition reprint (2010)	$100.00	$150.00
Modern DC-to-DC Switchmode Power Converter Circuits by Rudolf Severns and Ed Blooom - reprint (2009)	$100.00	$150.00
Applications of Magnetism by J. K. Watson - Reprint (2008)	$50.00	$100.00
Handbook of Standardized Terminology for the Power Sources Industry- (Third edition – 2007)	$25.00	$50.00
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