Abstracts

Session 4 – Waste Heat Utilization

THERMOELECTRICAL ENERGY RECOVERY FROM THE EXHAUST OF A LIGHT TRUCK

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ABSTRACT

A team formed by Clarkson University is engaged in a project to design, build, test, and develop a plan to commercialize a thermoelectric generator (TEG) for recovering some of the energy in the exhaust from light trucks and passenger cars. The team members are Clarkson University (project management, vehicle inter-face design, system modeling, commercialization plan), Hi-Z Technology, Inc. (TEG design and construction, subcontractor to Clarkson), Delphi Automotive Systems (testing services and engi-neering consultation), and General Motors, Inc. (test vehicle).

Funds were supplied by a grant from the Transportation Research Program of the New York State Energy Research and Development Authority (Joseph Wagner, Project Manager). Members of the team and the U.S. Department of Energy's Office of FreedomCAR and Vehicle Technologies (John Fairbanks, Project Manager) supplied cost-sharing and in-kind support. General Motors loaned the test truck (a 1999 Sierra) and supplied information about its sys-tems. Delphi Automotive Systems, Inc., supplies engineering consulting services and will furnish 2 weeks of testing time at its Lockport, New York, facility.

The TEG consists of 16 HZ-20 modules connected in series, clamped between the ex-haust and coolant heat exchangers and elec-trically connected to the DC bus through a power-conditioning unit. It will be capable of generating 330 W of electric power when it op-erates at its design temperature differential. The exhaust from the test truck's 270 hp V8 gasoline engine passes through the two catalytic con-verters located near the left and right sides of the truck frame and then will be routed through the TEG. To provide for reliable thermoelectric module cooling, the TEG will be integrated into the truck engine cooling system.

This presentation will: (1) show some of the results of initial studies using a model that incorporates the TEG system into the National Renewable Energy Laboratory's ADVISOR ve-hicle simulation code, (2) discuss the principal conclusions of a market survey done for the project's draft commercialization plan, and (3) summarize the first portion of the Phase 2 work now underway.

SCALE-UP OF $Si/Si_{0.8}Ge_{0.2}$ AND B_4C/B_9C SUPERLATTICES FOR HARVESTING OF WASTE HEAT IN DIESEL ENGINES

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ABSTRACT

Thermoelectric devices show significant promise for harvesting and recovery of waste heat from diesel engines, exhaust sys-tems, and industrial heat sources. Con-version efficiencies of bulk thermoelectric systems, however, are still too low for eco-nomical power conversion in diesel-powered vehicles and heavy vehicles.

Thermoelectric superlattice devices have demonstrated the potential for increased efficiencies and utilization of waste heat. Although reported efficiencies are well above 15 percent, fabrication costs are still too high for use in diesel engine systems. To realize this efficiency goal of ~20% and power generation in the kW-MW range, large quantities of superlattice materials are required. Additionally, if the figure of merit (ZT) of these superlattices can be increased to > 2, even less superlattice material will be required to generate electric power from heat in diesel engines.

We report on development of and recent progress in scale-up of $Si/Si_{0.8}Ge_{0.2}$ and B_4C/B_9C superlattices for thermoelectric ap-plications, and particularly for fabrication of large quantities of these materials. We have scaled up the magnetron sputtering process to produce large quantities of $Si/Si_{0.8}Ge_{0.2}$ and B_4C/B_9C superlattices with high ZT at low cost. Superlattices with up to 1,000 layers were deposited onto substrate areas as large as 0.5 m^2 by magnetron sputtering.

Initial studies showed that the power factor of these superlattices was high enough to produce a ZT significantly greater than 1. Both p- and n-type superlattices were fab-ricated to form a complete thermoelectric power-generating device.

ZT measurements will be reported, and based on measured power factor of these materials, should be significantly greater than 1. These results are encouraging for the use of superlattice materials in thermo-electric power generation.

POTENTIAL THERMOELECTRIC APPLICATIONS IN DIESEL VEHICLES

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ABSTRACT

Novel thermodynamic cycles developed by BSST provide improvements by factors of approximately 2 in cooling, heating, and power generation efficiency of solid-state thermo-electric systems. The BSST technology is avai-lable now and is currently being evaluated in automotive development programs for important new applications. New thermoelectric materials are likely to become available that further in-crease performance by a comparable factor. These major advancements should allow the use of thermoelectric systems in new applications that have the prospect of contributing to emis-sions reduction, fuel economy, and improved user comfort.

Potential applications of thermoelectrics in diesel vehicles are identified and discussed. As a case in point, the history and status of the Climate Controlled Seat (CCS™) system from Amerigon, the parent of BSST, is presented. CCS is the most successful and highest production volume thermoelectric system in ve-hicles today. As a second example, the results of recent analyses on electric power generation from vehicle waste power are discussed. Con-clusions are drawn as to the practicality of waste power generation systems that incorporate BSST's thermodynamic cycle and advanced thermoelectric materials.

RECENT PROGRESS IN THE DEVELOPMENT OF HIGH-EFFICIENCY THERMOELECTRICS

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ABSTRACT

This paper will discuss the recent de-velopments of high-efficiency quantum well thermoelectrics at Hi-Z Technology, Inc. The performance of the latest P-type B_4C/B_9C – N-type Si/SiGe couple will be presented as well as data for the new N-type Si/SiC that will replace Si/SiGe and improve couple efficiency.

Preliminary calculations regarding the development of actual quantum well mod-ules will be presented for both power pre-diction and cooling applications. These modules can be used in future diesel exhaust energy conversion systems as well as air-conditioning system designs. The design of a family of small quantum well based generator wells being developed for wireless sensor systems will also be presented. These small generators use energy-har-vesting techniques to produce power for the system.

Our current efforts to produce quantum well films more rapidly will be discussed.

DESIGN AND DEVELOPMENT OF E-TURBO™ FOR SPORT UTILITY VEHICLE AND LIGHT-TRUCK APPLICATIONS

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ABSTRACT

The purpose of the project is to develop an electrically assisted turbocharger, e-Turbo™, for application to the sport utility vehicle (SUV) and light truck class of passenger vehicles. Earlier simulation work had shown the benefits of the e-Turbo™ system on increasing low-end torque and improving fuel economy. This paper will present further data to show that advanced turbocharging can enable diesel engine down-sizing of 10-30 percent with 6-17 percent im-provement in fuel economy. This is in addition to the fuel economy benefit that a turbocharged diesel engine offers over conventional gasoline engines. In this downsizing scenario, e-Turbo™ is necessary to recover acceptable driving char-acteristics with downsized diesel engines.

As a first step towards the development of this technology for SUV/light truck sized diesel engines (4-6 L displacement), design concepts and hardware were evaluated for a smaller engine (2 L displacement). This strategy was chosen to minimize design and development is-sues and then prove the concept in bench testing and small engine testing. Following small en-gine success, the concept could applied to a large V-engine (one on each bank) to prove target performance characteristics. After successful demonstration of concept and performance, large turbomachinery could be designed and built spe-cifically for larger SUV-sized diesel engines. This paper presents the results of development of e-Turbo for a 2 L diesel engine.

A detailed evaluation of motor-generator and turbocharger requirements and designs has been performed, including comparison of different motor-generator technologies and dif-ferent motor-generator/turbocharger integration schemes. Detailed analysis and bench testing have been performed to confirm basic design concepts and will be used to finalize product design for engine testing.

DIESEL ENGINE WASTE HEAT RECOVERY UTILIZING ELECTRIC TURBOCOMPOUND TECHNOLOGY

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ABSTRACT

Electric turbocompounding (ETC) is a way to recover exhaust heat energy and return it to the driveline. ETC integrates well into a MorElectric™ Initiative vehicle and allows previously unattainable level of con-trol of the engine air system. The primary goal is a 5-percent reduction in fuel con-sumption and/or emissions.

This presentation will report progress to date on a technology demonstration pro-gram. Component design and analysis as well as control system development will be reviewed. The ETC system requires a completely new control strategy and control system. Two electrical motor/generators, one on the turbo shaft and one on the crankshaft, are part of the ETC system; their design and test results on the dynamometer will be shown. Furthermore, design and per-formance test results of a newly developed turbocharger will be presented.