ABSTRACT BOOK

The 2nd Graduate Student Symposium
Dept. of Mechanical Engineering
Binghamton University (State University of New York)
Binghamton, New York 13902-6000

April 27, 2007

The 2nd Graduate Student Symposium of Mechanical and Materials Engineering

April 27, 2007

ITC Conference Room, Rm. 2221

8:30:	Opening Statements
8:40:	Morning session (Chair: Junghyun Cho)
8:40 – 9:00:	Biplab Roy (Thermodynamic Calculations for Aqueous Synthesis of Barium Titanate)
9:00 – 9:20:	Andy Zhang (Tailoring Nanostructure of Biomimetically Synthesized Ceramic Films)
9:20 – 9:40:	Mohammad Abuzaid (Direct Numerical Simulation of Biomimetic Ceramic Thin Film Coating)
9:40 – 9:50:	Break
9:50 – 10:10:	Abdulla Al-Yafawi (Avionics Reliability)
10:10 – 10:30:	Yong Zheng (CFD Model Of Two Flows Mixing In A Y-Shape Microchannel)
10:30 – 10:50:	Shijun Yu (Modeling of Thin Film Deposition Process: A Study on Vapor and Liquid Flow)
10:50 – 11:00	Break
11:00 – 11:20:	Babak Arfaei (Applications of Nanoindentation in the Evaluation of Mechanical Properties and Reliability of Sn-Ag-Cu Solders)
11:20 – 11:40:	Anjali Chauhan (Effect of Dwell Times on Wetting Performance of Sn on Cu/Au Surface Finishes)
11:40 – 12:00:	Fan Zhou (Thermo-Mechanical Analysis of Thru-Silicon-Via Based TiW Interconnect)
12:00 – 12:20:	Sushma Madduri (Non-hermetic Opto-electronic Packaging)
12:20 – 1:20:	Lunch
1:20:	Afternoon session (Chair: Bruce Murray)
1:20 – 1:40:	Mark Zsurka (Enhancement of the Diffusion of a Passive Scalar by the Introduction of a Particulate Phase in Microfluidic Channels)
1:40 – 2:00:	Siddharth Bhopte (Thermal Management of Data Center Clusters)
2:00 – 2:20:	Dylan Farnam (Comparative Analysis of Microchannel Cooling Schemes Subject to a Pressure Constraint)
2:20 – 2:30:	Break

2:30 – 2:50:	Kaikun Yang (Synthesis of Vertically Aligned Carbon Nanotubes)
2:50 – 3:10:	Yayong Liu (Aligned Carbon Nanotube Polymer Composite)
3:10 – 3:30:	Parthi Arunasalam (Design, Fabrication and Implementation of Smart Three Axis Compliant (STAC) Interconnects for Ultra-Thin Chip Stacking Technology)
3:30 – 3:40:	Break
3:40 – 4:00:	Kirill Zaychik (Operator Model Parameter Estimation Using Genetic Algorithms)
4:00 – 4:20:	Adam Van Buren (Quasi-Static and Dynamic Modeling of Fluid Inside a Tank Subjected to Various Accelerations)
4:20 – 4:40:	Fadi Al Saleem (Experimental and Theoretical Investigation of New Capacitive Switches Activated by Mechanical Shock and Acceleration)
4:40 – 5:00:	Da Yu (Cellphone Drop Test and Simulation)

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Thermodynamic Calculations for Aqueous Synthesis of Barium Titanate
By Biplab Roy (advisor: Junghyun Cho)

Barium Titanate ($BaTiO_3$) is a well-known ceramic material because of its application in capacitor technology (bulk dielectric constant ~1600). Solid state, co-precipitation, Pechini method are common synthetic routes for barium titanate at high temperatures (>750˚C). Deposition of $BaTiO_3$ thin films has also been made successfully by standard PVD and CVD methods. However, the new embedded capacitor technology in electronic packaging demands deposition of barium titanate thin films at low temperatures (<100˚C). Solution chemistry route involving aqueous inorganic precursors of Ti and Ba at low temperatures shows a high promise for in-situ chemical bath deposition of nano-structured $BaTiO_3$ films. The processing parameters such as pH, temperature, initial concentration barium and titanium and reaction time strongly influence nucleation, formation, crystal structure and properties of the resultant films.

This presentation aims to put forward a thermodynamic approach to calculate the reaction constants and Gibbs free energy at various experimental temperatures for reactions occurring in the chemical bath for $BaTiO_3$ synthesis. Debye Hückel theory of mean activity coefficient, Guggenheim approximation and several other models are employed to calculate the thermodynamic parameters. Finally, calculated parameters are employed to generate the stability diagram for several stable and meta-stable phases present in the chemical bath. To verify theoretical predictions, experimental results that tailor the formation behavior of $BaTiO_3$ in a chemical bath at low temperatures will be presented.

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Tailoring Nanostructure of Biomimetically Synthesized Ceramic Films
By Andy Zhang (advisor: Junghyun Cho)

A novel ceramic thin film deposition approach through which inorganic materials were deposited on a functionalized organic matrix from aqueous media at low temperatures was studied. This process is analogous to the natural biomineralization process. Specifically, nanostructured ZrO_2, TiO_2 and SnO_2 thin films were deposited at about 70°C by the hydrolysis of $Zr(SO_4)_2$, $TiCl_4$, and $SnCl_4$ aqueous precursor solutions, respectively, on silicon substrates coated with phosphonate-terminated self-assembled monolayers (SAMs). The as-deposited ZrO_2 and TiO_2 films consisted of nanocrystallites in size of 5-10 nm, while some amorphous phases existed as well. The principal mechanism for the formation of the films seems to be homogeneous nucleation of the bulk precipitates and their aggregation behavior in supersaturated solution.

The Derjaguin, Landau, Verwey and Overbeek (DLVO) theory was applied to disclose the mechanisms for the formation of the oxide films in the media of aqueous precursor solutions. The interactions of particle-substrate, particle-deposited film, and particle-particle all exhibit negative minimal energies, indicating that the initial and subsequent continuous depositions on SAM and bare silicon, as well as particle aggregation, are thermodynamically favorable. In

addition, the differences among the amplitudes of the minimal interaction energies may, however, reflect some preference of the deposition on SAMs to that on bare silicon.
In an effort to evaluate mechanical integrity of the as-deposited ceramic films, the intrinsic elastic moduli of the as-deposited ceramic films were determined by using dynamic nanoindentations. Dye leak tests suggest that the as-deposited ceramic films, especially the TiO_2 films, enhance significantly the hermeticity performance of the device coatings.

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Direct Numerical Simulation of Biomimetic Ceramic Thin Film Coating
By Mohammad Abuzaid (advisor: Ying Sun)

Ceramic thin film coating is usually done at a high temperature and because of that the coating process suffers from serious problems such as the shrinkage of the thin film which will result in crack propagation and poor morphological and microstructural properties. In recent years, Novel thin film coating methods have been adapted that can be achieved at relatively low temperature. These methods are mimicking the ceramic deposition processes that occur in nature like teeth growth and eggshell production. The theory behind the nucleation, growth, aggregation and deposition of ceramic nanoparticles is still not well established and needs a good deal of research activity in order to establish substantial models that can describe the physics of the ceramic deposition processes. Mainly, the driving forces of the aggregation and deposition processes are characterized as DLVO and Non-DLVO forces. The DLVO forces are van der waals forces and the electric double layer forces. The Non-DLVO forces can be included in DLVO theory as a hydration forces which include the steric forces, Born energy (electron shell overlapping) and hydrophobic/ hydrophilic forces. The current research is about building simulation tools that can be used by researchers to model the ceramic deposition process which will give them the benefit of having a robust and economical design of ceramic thin film coating experiments.

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Modeling of Thin Film Deposition Process: A Study on Vapor and Liquid Flow
By Shijun Yu (advisor: Junghyun Cho)

There are two steps involved in the process of SAM-assisted ceramic coatings: Self-assembly of monolayer on silicon substrate via vapor-phase deposition and subsequent deposition of ceramic coatings onto the SAM surface from aqueous solution. And it was observed that the uniformity of the SAMs or ceramic coatings depends much on the geometry of the reaction vessel and how the substrate is placed. A study on the flow in the reaction vessel is conducted based on different design of the reaction set-up. In the vapor-phase deposition, vertically positioned substrate produces SAM with a more uniform morphology. The liquid flow in our newly designed rectangular vessel for ceramic deposition is also studied and the optimization of the design will be made according to the simulation result.

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CFD Model of Two Flows Mixing in a Y-Shape Microchannel

By Yong Zheng (advisor: Ying Sun)

Investigating flows mixing in microchannels leads to significant understanding of the flowing mechanism of blood in vessels. In this paper, computational fluid dynamic (CFD) model was used to simulate a Y-shape microchannel to investigate the mixing mechanism of two flows. These laminar flows had very low Reynolds number less than 10. Several cases were studied to obtain the mixing mechanism. In first case, inlet flows were two distilled water flows with same velocity and the velocity vectors field was obtained to determine the fully developed distance in the outlet channel. The results were verified with the empirical experiment conducted by PIV in Microfluidic Lab. In second case, dyed distilled water and simple distilled water represented species A and B, respectively. The mass diffusivity equation was involved to calculate the mass diffusion in outlet channel. Human blood is Non-Newtonian fluid. In a more complicated case, we would expand the model to simulate Non-Newtonian fluid with suspension.

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Thermo-Mechanical Analysis of Thru-Silicon-Via Based TiW Interconnect

By Fan Zhou (advisor: Bruce Murray)

Detailed 3D FEM thermo-mechanical analysis is performed on a chip stack that utilizes the Smart Three Axis Compliant (STAC) interconnect, a TSV based ultra-high density compliant interconnect. These interconnects are microstructurally engineered to accommodate relative displacements between ultra-thin TSV based silicon chips and substrates to which they are bonded without transferring significant stress to the die itself. 3D numerical model of the TiW bi-metal layer compliant beam built with opposing stresses to establish z-axis lift-height that compares well with analytical results will be presented. With this validated model, a force-deflection curve is established for a 125μm×25μm×0.8μm TiW free beam with 1GPa stress built into its two metal layers (-500MPa in the bottom layer and +500MPa in the top layer). This will enable numerical characterization of the compliancy of a single interconnect. This analysis is followed by thermo-mechanical analysis of a unit cell STAC interconnect (TSV, copper bond pad and the compliant beam) built on a 50μm thick silicon die. Particular attention is given to stresses formed in the TSV copper column when temperature is varied from -40°C to 150°C.

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Applications of Nanoindentation in the Evaluation of Mechanical Properties and Reliability of Sn-Ag-Cu Solders

By Babak Arfaei (advisor: Junghyun Cho)

The demand for environmental initiatives within the electronics industry, such as the replacement of lead-tin solders, has increased in the last decade. Despite the fact that the removal of lead from solder has been accelerated by legislation in different parts of the world (especially in the case of the RoHS/WEEE directives in the EU), the lack of reliable information concerning the mechanical properties of Pb-free solder alloys and the intermetallic compounds (IMCs) resulting from the reflow process is still a major concern. This paper reports an investigation done on the Sn-Ag-Cu alloys, which are currently considered to be the best replacement for the Sn-Pb solder. In this study, nanoindentation is used to assess mechanical performance of individual constituents of Pb-free alloys (i.e., Sn-based matrix and various types of IMCs). One purpose of this research is to correlate the nanoindentation behavior to macroscopic solder performance in order to determine the relevance of nanoindentation work in evaluating the solder joint reliability. In order to identify the controlling deformation mechanisms at elevated temperatures; nanoindentation creep tests are also performed to measure the stress exponent and activation energy.

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Effect of Dwell Times on Wetting Performance of Sn on Cu/Au Surface Finishes

By Anjali Chauhan (advisor: Tim Singler)

Reactive wetting in metal-metal systems involves dissolutive wetting of molten metal on solid metal substrate. The wetting is characterized by the exceptional spreading behavior of the molten phase which varies with temperature and dwell times. Experiments employ wetting of pure Sn on 1μmAu/12μmCu via sessile drop technique. Wetting radius was recorded as a function of time and metallographic cross sectioning was done to investigate the temporal evolution of S/L interface.

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Avionics Reliability

By Abdulla Al-Yafawi (advisor: Seungbae Park)

In today’s world, electronics devices and parts control almost every aspects of our life, starting from nearly all household equipment to the most advanced space technology. However, the consequences of the failure of a safety or control system, onboard a civil or military aircraft or a space vehicle, are immeasurably more serious than a glitch in a consumer appliance or internet service delivery. For example, Avionics, which compromise a considerable fraction of cost and complexity of aircrafts, now perform critical vehicle control function, which in case of failure may lead to catastrophic disasters. Therefore, there is no doubt that the employment of such system is greatly dependant on the proper performance and system reliability under various operating conditions.

A research in ”Avionics Reliability” is mainly aiming, after reviewing the available literature; to identify the most common failure modes and mechanisms, to investigate the effect of different parameters, specially operating environment, on failure process, to survey reliability tests and standards and to develop and modify physical models to predict the reliability of components and systems.

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Non-hermetic Opto-electronic Packaging

By Sushma Madduri (advisor: Bahgat Sammakia)

The presentation is a summary of the literature survey, done on non-hermetic opto-electronic packages, focusing on the cost and reliability aspects. It sets off with an introduction to the concept of hermeticity in opto electronic packages, followed by a detailed study about the reliability issues and failure mechanisms observed in non hermetic packages when compared to their hermetic counter parts. Hermeticity is defined as a seal applied to electronic packages to prevent the entry of air, foreign gases, contaminants, and most importantly moisture. To seal a package hermetically is particularly challenging and expensive. There are various techniques that are investigated, to improve the reliability of non hermetic packages. A few of them are facet passivation type, better optical glasses, encapsulation techniques and silicon optical bench technology. Also some of the most common and important failure mechanisms like popcorn failure, adhesive degradation, laser misalignment and epoxy swelling are discussed. The goal of this study is to be able to achieve a low cost and highly reliable non hermetic package.

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Enhancement of the Diffusion of a Passive Scalar by the Introduction of a Particulate Phase in Microfluidic Channels

By Mark Zsurka (advisor: Tim Singler)

The mixing of fluids in micron-scale channels is dominated by low Reynolds number flow, effectively eliminating turbulence as a transport mechanism. As a consequence, Brownian diffusion becomes the dominant mechanism for mass transport in devices on this length scale. Promoting further mixing of the passive scalar necessitates the introduction of an auxiliary mechanism. The addition of a particulate phase into a pressure-driven shear flow has been shown to produce a shear migration effect whereby particles hydrodynamically diffuse into regions of lower shear. This can be attributed to the particle field’s form being defined by gradients in volume fraction, as well as in shear rate. Some evidence exists that the introduction of a second phase into such flows enhances mixing in microfluidic channels. An experimental apparatus has been created which will allow for these effects to be quantitatively assessed. Confocal microscopy, fluorescent imaging techniques, and image processing software are used to extract data from the experimental apparatus. This data includes the imaging of both the particulate and passive scalar fields. Methods for the visualization and analysis of the transport of both phases as well as problems encountered and experimental progress to date will be discussed.

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Thermal Management of Data Center Clusters

By Siddharth Bhopte (advisor: Bahgat Sammakia and Bruce Murray)

Data centers are facilities that house large numbers of computer servers that dissipate high power. With the rapid increase in the heat flux of such systems, their thermal management has become a challenge that needs to be addressed. Computational analyses using a CFD code is a very useful technique that helps the engineer to understand and solve the data center cooling problem. In this presentation the state of the art of numerical modeling of data center will be discussed.

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Comparative Analysis of Microchannel Cooling Schemes Subject to a Pressure Constraint

By Dylan Farnam (advisor: Bahgat Sammakia)

Leakage losses and overall increased power dissipation in the microprocessor are causing significant thermal, mechanical, and reliability problems. Aside from the issue of cooling chip hot spots in order to reduce stress-inducing thermal gradients, the traditional challenge of quelling overall operating temperatures remains. Conventional cooling methods are reaching their practical limits and new methods of lowering the operating temperature of microprocessors are being explored. Microfluidics-based cooling schemes are one approach being considered. Implementation of microchannels for forced convection at the chip level shows much promise, as the effective heat transfer surface area and attainable heat transfer coefficient are very favorable. A major design limitation to such an implementation is the pressure developed with such micro-flows, and the stresses that could result. In this study, multiple discrete microchannel configurations are analyzed computationally and compared in a cooling capability optimization sense, while total pressure drop across the flows is carefully considered. A single cooling channel over an energy source is split into two smaller channels, and so on, while total pressure drop is maintained constant, and specified such that all flows remain in the laminar regime. It is shown that for the configurations analyzed, there exists a definitive optimum cooling scheme. In addition, the effects of variation of channel height for the initially-determined optimum scheme are studied. It is shown that a slimmer design may be implemented with very little effect on cooling capability.

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Synthesis of Vertically Aligned Carbon Nanotubes

By Kaikun Yang (advisor: Howard Wang)

Vertically aligned carbon nanotubes (VACNTs) have gained more and more attention for innovative applications as nanotubes membranes, nanotubes filter, nanotube yarns, three-dimensional microbatteries because of their remarkable properties. In our experiments, catalytic Fe thin films were coated on SiO_2 /Si substrates in a pulsed-laser deposition system. Chemical vapor deposition (CVD) at atmosphere pressure is involved to deposit VACNTs using carbon-bearing gas as the carbon source, and argon and hydrogen as carrier gases. The as-grow VACNTs are characterized by transmission electron microscopy (TEM), scanning electron microscopy (SEM) and Raman spectroscopy. The VACNTs growth is guided by a growth model that combined the dissociative adsorption of carbon-bearing molecules and the successive vapor-liquid-solid growth mechanism. The key factor for growing these VACNTs is a balance between the decomposition rate of carbon–bearing molecules on the iron catalyst and the subsequent diffusion and segregation rates of carbon.

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Aligned Carbon Nanotube Polymer Composite
By Yayong Liu (advisor: Howard Wang)

We have investigated the preparation of Vertically aligned CNT (VACNT)-polystyrene (PS) composites and characterized their morphologies and properties. VACNTs remain unaltered upon forming composites. Nanoindentation tests show that both the elastic modulus and hardness vary along the CNT growth direction due to the varying tube density, alignment order and entanglement as revealed by field emission scanning electron microscopy (FESEM) and small angle neutron scattering (SANS).

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Design, Fabrication and Implementation of Smart Three Axis Compliant (STAC) Interconnects for Ultra-Thin Chip Stacking Technology
By Parthi Arunasalam (advisor: Harold Ackler)

This presentation will report the current status of a novel MEMS based ultra-high density compliant interconnect for ultra-thin chip stacking technology. These highly compliant interconnect, which we call Smart Three Axis Compliant (STAC) interconnects are directly fabricated onto electrical contact pads or thru-silicon vias on die at the wafer-level. The interconnects are bound to the die by a chemically soluble release layer. The “free” end of the interconnect is bonded to a contact pad on a package substrate or other die at the wafer level or die level, and the release layer is dissolved to free the interconnect from the substrate, thereby permitting it to accommodate relative displacements. The presentation will clearly show successfully fabricated STAC interconnects (50micron pitch) on a silicon die bonded onto an ultra-thin die.

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Operator Model Parameter Estimation Using Genetic Algorithms
By Kirill Zaychik (advisor: Frank Cardullo)

Modeling of the human operator is an essential part of any type of man-machine system analysis. Over the years a number of operator models, invented by the world recognized researchers such as McRuer, Smith, Hess, Kleinman is presented. The brief description of the Hess operator model is given in this section. The thrust of the work is the development of the methodology of an automated tuning of the parameters of the modified Hess model. The proposed algorithm heavily involves the machine learning tools otherwise known as soft computing techniques, such as Fuzzy Inference Systems, Neural Networks, Adaptive Neural Nets etc.

The presentation focuses on details of implementation of soft-computing techniques, namely Genetic Algorithms, in an attempt to continuously estimate parameters of the modified Hess model. Description of the proposed Parameter Identification Technique (PID) technique as well as appropriate block-diagrams and flowcharts are presented. Preliminary results presented are based on the data obtained by simulating a simple manual control task. It is demonstrated that proposed PID technique is capable of simultaneously estimating several (five) parameters of the Hess model. Graphs included in this presentation illustrate that estimated operator behavior is almost identical to the actual behavior of the simulated human operator. The concluding part of the talk discusses pros and cons of the proposed technique as well as ways to improve its performance.

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Quasi-Static and Dynamic Modeling of Fluid Inside a Tank Subjected to Various Accelerations

By Adam Van Buren (advisor: Frank Cardullo)

The behavior of a fluid mass inside a tank subjected to various accelerations in the lateral and longitudinal directions is analyzed through the use of a quasi-static approach and a dynamic approach. The quasi-static approach uses the hydrostatic equation of fluid mechanics, derived from a force balance on an incompressible fluid element in static equilibrium, to model the fluid surface due to an applied acceleration. The dynamic approach uses an equivalent mechanical model of the fluid mass consisting of a pendulum with a spring and dashpot that account for the viscous and restoring forces of the fluid. Mass properties of the fluid, including the principal moments of inertia, are calculated using an energy method approach involving a velocity potential function. The center of gravity of the fluid is determined through integration over the x, y, and z bounds of the fluid in the quasi-static approach and through analysis of the pendulum governing equation in the dynamic simulation. The quasi-static and dynamic models, which accurately calculate the changing x, y, and z-components of the fluid center of gravity for various acceleration inputs, will be integrated with a vehicle dynamics model and used to improve the functionality of driving simulators.

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Switches Activated by Mechanical Shock and Acceleration

By Fadi Al Saleem (advisor: Mohammad Younis)

This work presents experimental and theoretical investigation into the characteristics and performance of a new class of switches (triggers) actuated at or beyond a specific level of mechanical shock or acceleration. The principle of operation of the switches is based on dynamic pull-in instability induced by the combined interaction between electrostatic and mechanical shock forces. Two commercial off-the-shelf capacitive accelerometers operating in air are tested under mechanical shock and electrostatic loading. A single-degree-of-freedom model accounting for squeeze-film damping, electrostatic forces, and mechanical shock is utilized for the theoretical investigation. Good agreement is found between the simulation results and experimental data.

Our results indicate that designing these new switches to respond quasi-statically to mechanical shock makes them robust against variations in shock shape and duration. More importantly, this makes the switches insensitive to variations in damping conditions. This can be promising to lower the cost of packaging for these switches since they can operate in atmospheric pressure with no hermetic sealing or costly package required.

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Cellphone Drop Test and Simulation

By Da Yu (advisor: Seungbae Park)

As portable electronic products, such as cell phone, are widely used in our daily life, the product’s impact durability becomes an extremely important design requirement. Drop shock is the major cause of structural failure for portable electronic products, therefore the free drop test has become one of the most crucial evaluations for these products. In this study, both free drop test and simulation are established to verify each other. We carry out simulation of the case shapes and battery weight distribution of the cell phone using LS-DYNA. The free drop test is to verify the simulation with real data. Then, the PCB stiffeners modeling and testing will provide us with improvement of the PCB design quality.