

University of Arkansas College of Engineering
High Density Electronics Center
Policies and Procedures

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Section 1. High Density Electronic Center Overview

1.1. Program of Excellence

Since its inception, the University of Arkansas' High Density Electronics Center (HiDEC) has pursued a program of excellence in research and education that has earned the program a national and international reputation. Several U.S. patents have been issued on HiDEC inventions and a number are pending. HiDEC papers are regularly presented at every major conference dealing with electronic packaging or packaging materials.

Several HiDEC research projects have been funded by, and performed for, companies in the electronic, biomedical, and aerospace industry. Projects have ranged from simple MCM designs to an entire technology development and reliability evaluation.

UA graduate students have a unique opportunity to pursue a degree with an emphasis in electronic systems and multichip technology. Extensive hands-on laboratory experience has led graduates to exceptional jobs in industry with leading companies such as Advanced Micro Devices, Anadigics, Harris, IBM, Integrated Device Technology, Intel, Lucent Technologies, Micron Technology, Motorola, National Semiconductor, Northrop Grumman, Raytheon, Sheldahl, and Texas Instruments.

1.2. Brief History

The research center began as an outgrowth of work conducted on thallium-based high temperature superconducting materials and their subsequent application to superconducting multichip modules (MCMs). HiDEC research has expanded to include work on synthetic diamond MCM substrates, low cost MCM design techniques, flip chip die attachment, integrated passive components, and other aspects of high density electronic packaging. The thin film facility originated from a partnership between the University of Arkansas and nChip that involved renovating a Truck and Tractor repair building into a thin-film processing lab. Operational in 1993, the HiDEC facility includes nearly 4,000 sq. ft. of cleanroom space initially specified at class 1000/100 (ISO class 6/5 respectively) for conventional MCM processing on 125 mm wafers. The HiDEC complex also began with reliability, wideband electrical characterization, and CAD laboratories in the adjacent UA Engineering Research Center and has since expanded these capabilities.

1.3. Mission

HiDEC's mission is to:

1. Promote and support University-based, faculty-lead research by providing staffed research laboratories in which they can execute their research.

2. Promote education by supporting lab-based University courses and by the teaching of fabrication courses by HiDEC staff.
3. Provide opportunities for outreach to Arkansas high- and middle-school students to encourage them to pursue engineering and/or science careers.
4. Stimulate growth of high-technology businesses in Arkansas by making facilities available to small, Arkansas-based technology companies, thus allowing them to better leverage their own research funding.

1.4. Core Competencies

HiDEC’s expertise can be organized under six general headings: MCM technology, LTCC technology, Integrated Passives, MEMS, Analysis/Reliability, and CAD/CAM. A limited list of skills in these areas is show below:

MCM Technology

- Silicon, ceramic, and polymer-based substrates
- MCM/Ball Grid Array/Flex
- MCM D/L and D/C Substrates
- 3-D MCMs
- Packaging of SiC-based power devices

LTCC Technology

- LTCC fabrication from design to testing
- Cavities
- Full tape thickness features

Integral Passives

- Resistors
- Capacitors
- Inductors

MEMS

- MEMS Design and Processing

Analysis/Reliability

- Thermal Stress Modeling & Evaluation
- Thermal shock / thermal cycling
- Wafer-level probing and yield analysis

CAD/CAM

- MCM/PCB design
- LTCC design
- Artwork conversion

1.5. Center Capability Overview

The Center consists of thin- and thick-film manufacturing labs, as well as satellite lab facilities that provide additional fabrication and characterization capabilities, including the following:

| | | |
|---------------------------|-----------|--|
| HiDEC Thin Film | HDEC 101 | PECVD, PVD, RIE, Diffusion, Oxidation, Electroplating, Contact Lithography, ICP, Profilometer, Ellipsometer, Critical dimension tool, IR oven, Aerosol jet printer |
| HiDEC Thick Film | ENRC-4802 | CNC via punching, Screen printing, Vacuum sealing and lamination, Hot knife cutter, Firing ovens |
| Thick Film (cont.) | ENRC-4501 | Firing ovens, Fume hoods, Heated press |
| Assembly | ENRC-4514 | Wire bonder, Dicing saw, Reflow station, Reflow ovens, Flip chip bonder |

| | | |
|------------------------------------|-----------|---|
| Reliability | ENRC-4312 | Thermal Shock, Temperature cycling |
| Electrical Characterization | ENRC-4316 | Flying probe tester, Thin film stress tool, Impedance analyzer, Network analyzer, Pull tester |
| Analytical | ENRC-4308 | 3D Printer, Scanning acoustic microscope, Cross-section lab & microscope, CNC milling machine, SEM sputter coater, Pull test & Die shear tester, Profilometer |
| Nano-Synthesis Lab | ENRC-4607 | Acoustic mixer, Ball mill, Centrifuge, Critical point dryer, Cryogenic probe station, Low humidity glove box, Magnetometer, Micropore physisorption analyzer, UV spectrophotometer, X-ray diffraction |

Section 2. Lab Access and Fees

2.1. Access

2.1.1. HiDEC User classification and Rates

HiDEC’s fee schedule is shown below and addresses the lab rate for two different user types:

- **Center Sponsored users** are users (academic or otherwise) who have added HiDEC as research center unit in the combined credit split section in RazorGrant managed by the University of Arkansas Research & Sponsored Programs. The details of how to add HiDEC as a research center is available at the following link: <https://research.uark.edu/units/rssp/razorgrant/>. The specific percentages for the two categories (Responsibility & Recognition and RIF distribution) should be discussed with the center director before beginning the RazorGrant submission.
- **Academic users** are entities with a RazorGrant generated cost center number but have not included HiDEC in the combined credit split section thus their base rate will have a 20% surcharge.
- **Service Center users** are entities who do not provide a cost center number generated on RazorGrant.

Before utilizing any HiDEC facility, all lab users must undergo the HiDEC orientation (Phase II Right-to-know) session. More detailed information on the requirements of this Phase II orientation is given below under Section 3.3. Note that **external companies that have employees in the cleanroom will need to have proof of liability insurance on file with HiDEC before entering the cleanroom.**

Table 1: HiDEC Facility Rate Fee (Rates shown are for fiscal year 2018 and are subject to change)

| Activity | Description | User Categories | |
|----------------------------|--|---|--|
| | | Center Sponsored Users /(Academic Users) | Service Center Users |
| Laboratory Rates | Base Rate | \$60/hour/ (\$72/hour) ¹ | \$90 |
| Staff support ² | Fabrication, design, Training ³ | Staff salary | Staff salary + F&A rate³ |

| Misc. charges | Supplies | At Cost | Cost + F&A rate |
|---------------|----------|---------|-----------------|
|---------------|----------|---------|-----------------|

¹ Non-Centered users will be charged an additional 20%

² Staff support charges are in addition to lab charges calculated on an hourly rate that includes both salary and fringe.

³ For all training, lab charges are billed for only one user. This applies when staff or certified student trains another.

2.1.2. Laboratory Rates

Except where noted in section 2.1.7, charges are billed in quarter hour increments and are based on time spent in the cleanroom or lab as opposed to specific equipment utilized. Charges begin from the time the student enters the door of the facility and ends when he/she leaves. Therefore, it is important for everyone to log in and out. Typically, lab fees are collected on a monthly basis, although this schedule can be adjusted if warranted by the needs of a sponsor.

2.1.3. Logout Violations

For each instance where a user fails to provide a log out time they are charged a logout violation fee that is equivalent to four hours in the cleanroom at the user's scheduled lab rate.

2.1.4. Staff Support

Staff support charges are for process training and support. The HiDEC orientation session (Phase II Right-to-know) is free. Staff is available to answer questions and offer advice without charge within reason; however, projects that require major technical assistance (project consultation exceeding a cumulative two hours and/or hands-on support) will be subject to staff support charges. To facilitate better communication, researchers are encouraged to structure projects as joint research efforts with staff members whenever possible.

2.1.5. Reliability & Analytical Equipment Rates

Equipment in these two areas is generally covered by the standard hourly rate (i.e. scanning acoustic microscope (SAM), cross-sectioning microscope, Dage Bond tester, and Relative humidity chamber). For a few tools however, an individualized charge rate has been established. Please review the rates below for the system you are interested in using.

85/85 Relative Humidity Chamber is \$2.00/hour (\$3.00/hour for external clients). The time is determined by the amount of time the tool is reserved for the testing. Please budget accordingly as a 1,000 hour run can cost from \$2,000 to 3,000.

Delta thermal cycling oven is \$2.00/hour (\$3.00/hour for external clients). If cycling is utilized, the hour rate is found by determining the duration associated with one cycle; with includes a ramp and soak times at each extreme. There is an additional charge for using liquid nitrogen (in liters) should that be needed and this amount is found by determining the number of cycles that can be run on a 180 L dewar. If staff is requested to prepare a dewar, a minimum 1 hour staff-assist charge will be applied for this service.

Tabai thermal shock system is \$2.75/hour (\$4.00/hour for external clients). The time is determined by taking the total number of cycles run times the amount of time required per cycle. Clients are welcome to utilize any existing thermal shock liquid present in the two tanks, but new liquid will need to be purchased separately at the user's expense.

Makerbot 3D printer is \$3.00/hour (\$4.40/hour for external clients). The time can be obtained by the software once a design is loaded into the software by using the "Preview" option. A separate charge of \$0.15/gram will be added if HiDEC supplied filament material is used, although users are welcome to provide their own filament.

Hirayama autoclave is \$1.36/hour (\$2.00/hour for external clients).

CNC milling machine is \$10.00/hour (\$15.00/hour for external clients). A separate charge (typically

\$40) will be applied per broken bit during milling if HiDEC supplied bits are used. Users are welcome and encouraged to provide their own bits or make arrangements for supplies to be purchased by HiDEC ahead of time.

2.1.6. Supplies

Supplies that are covered under the standard lab fee include general consumables such as commonly used chemicals, gloves, hair nets, and cleanroom paper. Supplies that fall under the category of “Miscellaneous Charges” include wafers, wafer tweezers, cleanroom notebooks, dicing blades, CNC bits and other similar items.

2.2. **Intellectual Property and Proprietary Research**

The University of Arkansas and HiDEC pursue academic and research endeavors in an open environment. From the academic side, this means HiDEC will not exclude any individual based on nationality attending any scheduled lab courses run through one of our laboratories. From the research end, this means that HiDEC is committed to freedom of access by all interested parties to our facilities. While most work conducted at HiDEC falls under public scrutiny, a certain amount of proprietary research is also pursued. **By default, the University of Arkansas and HiDEC regard the nature of the work carried out by any external lab user as confidential and, thus, will not attempt to claim intellectual property developed independently by external clients using the lab.**

Both academic and industrial users can be present in HiDEC labs at any given time. **HiDEC does not generally provide secure storage locations for project supplies or materials, although some limited storage is available.** The Center makes any and all possible efforts to comply with export control concerns. However, **it is the responsibility of principal investigators to assure that any concerns regarding confidentiality or export controls be addressed for their respective project.**

For more specific details, all users are strongly encouraged to refer to the University of Arkansas’ Policy on intellectual property.

2.3. **Course Offerings**

The table below shows a list of classes conducted using HiDEC facilities:

| Classification | Course Description | Course Number |
|---------------------|-----------------------------|---------------|
| Transferred Courses | Integrated Circuit Fab. Lab | ELEG 5293L |
| | Solar Cell Fab. Lab | ELEG 4223 |
| Staff Taught | ELEG 587V: Microfabrication | ELEG 5243L |
| Staff Assisted | ELEG 587: MEMS Fabrication | |

2.3.1. Transferred courses

Transferred are those that were formerly taught in Bell Engineering’s Texas Instrument’s Research Facility that have now been transferred to HiDEC. An electrical engineering professor and his/her associated teaching assistant conduct these classes with departmental support that serves to cover cost associated with the course.

2.3.2. Staff-taught courses

Staff-taught are those classes providing both a theoretical and hands-on training on equipment and capabilities at HiDEC. The current course offering, *ELEG 5243L: Microelectronic Fabrication Techniques and Procedures*, has been in place since 2004. In the near future, HiDEC envisions that similar classes will be taught covering LTCC, assembly, and design aspects of advanced electronic packaging. As with the course currently being taught, courses under this section would be taught by HiDEC research staff during standard working hours during the Fall semester with departmental support in the form of a **\$1,300 monthly fee** that serves to cover cost associated with the course.

2.3.3. Staff-assist or Professor-led courses

These courses are regular lecture courses that wish to add a 'lab' portion to better improve the understanding of the material or to provide limited fabrication support. They are conducted by faculty with departmental support to subsidize the cost of materials and supplies consumed during the course.

Regardless of the course type, these general rules apply when a class utilizes HiDEC facilities:

- The number of students in a class is not to exceed 10 at any one time.
- No more than one course may be held during the same time period; to insure the limitation is adhered to; instructors must consult with the HiDEC Director and Staff a semester in advance about potential scheduling conflicts with other courses.
- For liability reasons, all students in the course must take the HiDEC Phase II Right to Know orientation prior to entering any HiDEC facility.

2.4. Reporting & Acknowledgement

HiDEC generates periodic reports that provide comprehensive statistics on its research efforts and activities. In order to prepare this report, we ask that all users provide a general summary of their research progress annually. Reports should not only include the status of the work, but also technical obstacles that could be overcome with alternative resources; such information can be used to dictate and justify future spending on infrastructure and equipment.

We also ask that all users provide acknowledgement of all research efforts utilizing HiDEC in publications with a sentence that reads "This research was made possible through the use of the High Density Electronics Center (HiDEC) at the University of Arkansas, Fayetteville," or by using a similar statement. Presentations should acknowledge HiDEC as well, when appropriate.

It is requested that HiDEC staff be informed of the date and particular conference where research is presented that made use of HiDEC resources and that a copy of any publications be provided for inclusion in the HiDEC library.

Section 3. Laboratory Information

3.1 CAD Resources

The HiDEC Design Laboratory is capable of handling the entire process of mask fabrication. The lab can provide services that include (but are not limited to) design consulting, schematic capture, artwork conversion, design optimization, and production of printed circuit boards for prototyping purposes. Our tool set includes industry standards such as Autodesk's AutoCAD 2015™, and DownStream Technologies' CAM350™. We also possess GDS-to- DXF and GDS-to-Gerber conversion utilities and are able to generate the necessary data for automated testing.

HiDEC's source for masks with improved resolution is Advance Reproductions, Inc. (<http://www.advancerepro.com/>). Their photo plots allow minimum feature sizes of approximately 15 microns; for features smaller than this, glass photomasks are needed. A specification and typical cost of these items is shown in the table below. Note that a photomask's minimum feature is usually one or two microns, but HiDEC's contact lithography capabilities are limited to two microns. Photo plots and glass photomasks are always shipped via FedEx Priority Overnight shipping, unless otherwise specified.

| Mask Type | Specification (Min. Feature / plot size) | Cost Range |
|-----------------------|--|--|
| In-house photo plots | 0.005" / 11 x 14" approx. | (staff standard labor rate, billed hourly) |
| Outsourced photoplots | 15 microns min. feature / 20 x 24" | \$50-\$150 (plus taxes and shipping), depending on resolution |
| Outsourced photomasks | 150 x 150mm or 175x175mm | \$500 to \$1500 (plus taxes/ shipping), depending on critical dimension in design and plate size |

3.2. Electrical characterization resources

The HiDEC Electrical Characterization Laboratory contains the tools needed to electrically test structures and systems. The AT&T automated flying two-probe, double-sided tester is used to measure interconnect integrity and isolation on wafers and LTCC substrates up to 150mm in size. The manually operated L117 Gaertner ellipsometer is used to characterize transparent thin films and the Tencor FLX2320A analyzes thin film stresses. The Materials Development Corporation's CSM16 CV plotter is used to evaluate MOS parameters while the HP4291A RF impedance/material analyzer and HP8510 network analyzer are used to characterize integrated passives (capacitors, resistors and inductors), though the latter can also provide evaluation of active devices as well. Other measurement instruments are available as well. A HiDEC staff member should be contacted to answer questions regarding access, training, and certification.

3.3. Storage

3.3.1. Cleanroom

To facilitate equipment use in the cleanroom during the day, HiDEC provides blue process boxes and corresponding PFA wafer boats for both 100 and 125mm wafers. The wafer boats are composed of a material that can survive any hazardous chemicals present in the lab, and the spin rinse dryers have been balanced using the weight of these boats. These wafer boxes and boats are not to be used for storage at any time. Students will need to have their own storage boxes to keep their processed wafers at the end of every day. Although the cleanroom has limited space for long-term storage, areas have been set-aside for some of the long-term projects and for staff use. Users are encouraged to find alternative space for processed wafers or mask sets that require storage longer than one month. HiDEC staff will clean out old wafers and mask sets at the end of each year.

3.3.2. Warehouse

HiDEC utilizes a warehouse located off the ENRC premises for long-term storage of functional accessories for the current set of process equipment in the cleanroom. HiDEC staff members attempt to maintain an inventory of equipment accessories (such as vacuum pumps and chillers) readily available to replace units that fail to insure minimal downtime. The warehouse is not intended to store unused process equipment. A tool that cannot be utilized by HiDEC directly or by a sister laboratory on campus will be turned over to the University's surplus warehouse in a timely manner.

3.4. Certification

3.4.1. Overview

All users must attend the HiDEC orientation session, also known as the "Safety Training" or "Right-to-Know" session, before entering the cleanroom. This is the second part of a two-phase right-to-know program implemented by the University of Arkansas' Environmental Health and Safety department that details the hazards and safety concerns specific to the laboratories at the Engineering Research Center.

3.4.2. The HiDEC Orientation

The HiDEC orientation consists of a 40 minute PowerPoint presentation specific to the HiDEC facilities, a cleanroom gowning demonstration, and a tour describing the equipment and processes available in the cleanroom facility. Even though HiDEC provides safety training as a part of their admission to the HiDEC facilities, supervising professors are ultimately responsible for the safety of their students and post-doctoral fellows since they are instructed by their supervising professors to perform work in HiDEC facilities. As such, HiDEC cannot assume any liability for any students or post-doctoral fellows.

3.4.3. Handouts

A new user will be given a cost center form that details cleanroom fees. This cost center form is proof that the advisor/employer has read and understands the rates and agrees to support the user on either a cost center number or via external billing. External (Genesis/ARTP) clients need only to enter the word 'external' instead of a cost center number. Users can return this form any time before they need to enter the cleanroom.

3.4.4. Cleanroom Entry by Visitors

With prior arrangement, visitors may enter the cleanroom for touring purposes without undergoing the

certification process, provided they are accompanied by a HiDEC staff member and/or approved tour guide at all times. Visitors should still be made aware of key safety information, including the location of fire extinguishers, telephones, and exits immediately after entering.

3.4. Equipment Use & Training

Before using a laboratory tool alone, ALL users must first complete the process of **certification**. To complete this process, a user must make an appointment with a HiDEC staff member and demonstrate to that staff member that they can operate the tool properly and safely. The certification process **MUST** be completed by any lab user (whether a student or an external user) before they use a tool on their own, either during regular office hours or after-hours. The staff member will then make a determination if the user is capable of operating the tool without supervision.

Users that use a tool on their own without first completing certification may risk being banned from the cleanroom temporarily or (if warranted by the flagrancy of the violation) permanently.

HiDEC staff members normally conduct equipment training sessions. However, a student that is proficient with a particular tool can demonstrate the tool's operation to new students and can even allow them to operate the tool in their presence. Similarly, external clients that are proficient with a tool may provide training for others, so long as they have been certified to use the tool themselves.

3.4.1. Reserving equipment

Reservation calendars are online at <https://uasharepoint.uark.edu/sites/hidec/default.aspx> to select process tools that require an extensive amount of time to use or that have a high demand. The following practices below apply when making reservations:

1. The user should attempt to accurately gauge use and avoid reserving large blocks of time. Students are not allowed to reserve a tool for more than 4 hours in a single day; exceptions to this rule must be approved by the HiDEC staff member in charge of the lab in which the equipment is located.
2. The user should cancel any reservation that they know they cannot keep.
3. There is a 15 minute window that begins at the scheduled reservation time during which a user must begin using the tool. If a user fails to begin using the tool during this time, the reservation is deemed forfeit and the tool becomes available to other certified users.

3.4.2. Reporting equipment problems

Any user who has a problem with a tool needs to contact a staff member either via email, phone, or in-person so that the problem can be resolved promptly. Some tools have the following identification markers to note its status:

1. **Up** indicates that a tool is functional and a certified user can begin operation.
2. **In Use** indicates that the tool is currently being utilized.
3. **Out of Order** indicates that the tool requires repair, preventative maintenance, or staff intervention before being utilized by users.

3.4.3. Accident/Incident/Unsafe condition reporting

Incident reporting is essential to ensure adequate preventative action is taken following an incident and is required by the University.

1. **Level I Incidents are those associated with violations that put only the offender at risk**
 - a. Example;
 - i. Personal attire violation (shorts & sandals)
 - b. Prior notification structure;

- i. Proper procedure presented in HiDEC orientation session.
- c. Penalty;
 - i. First violation results in a written report to user, the associated advisor, HiDEC staff and director.
 - ii. Repeat violation results in access suspension of HiDEC facilities.
2. **Level II Incidents are those associated with violations that endanger not only the offending party, but possibly other lab users as well.**
 - a. Example;
 - i. Chemical handling violation, equipment/process usage violation
 - b. Prior notification structure;
 - i. Proper procedure presented in HiDEC orientation session.
 - c. Penalty;
 - i. First violation results in a written report to user, the associated advisor, HiDEC staff, and director.
 - ii. Repeat violation results in access suspension of HiDEC facilities.
3. **Level III Incidents are those that endanger anyone through the circumvention of existing safety measures or by intentionally deviating from posted procedures intended to protect the safety of the offender or other lab users.** These incident types are considered the most serious, because they demonstrate an active attempt to dismiss safety concerns in an attempt to take “shortcuts”.
 - a. Example;
 - i. Violating the Buddy System
 - ii. Mixing chemicals without staff supervision and/or permission
 - iii. Intentional circumvention of equipment safety interlocks
 - iv. Using equipment unsupervised without first being “certified” by HiDEC staff
 - b. Prior notification structure;
 - i. Presented in the HiDEC policy, orientation, and posted on facility entryways.
 - c. Penalty;
 - i. A single violation warrants banishment from all HiDEC facilities.

3.5. Lab Policy

3.5.1. Card Reader Access

Access to the labs is obtained through a University-distributed ID card. Information on how to have a card encoded to access the various HiDEC facilities is available through the HiDEC orientation session.

External users (employees of companies in the Arkansas Research Technology Park and elsewhere) should apply for an “Affiliate” card at the ID card office in the Arkansas Union. **Users doing this should be certain to tell the person in the ID card office that they need their ID card encoded for card reader access.**

Due to safety and other concerns, card reader access to a given laboratory will only be issued after the lab manager for that particular laboratory has sent an email to the HiDEC staff member responsible for granting card reader access indicating their approval to grant access.

3.5.2. Keys

Access to most HiDEC lab facilities is controlled via the University ID card reader system. Office keys are acquired through the HiDEC key administrator after the HiDEC director and/or the Department Head of Electrical Engineering have given their approval.

Since access to practically all laboratories is controlled via card reader units, keys to laboratory areas will be issued only in special cases. Before a key can be issued, the lab manager for a particular lab **MUST** send an email to the HiDEC key administrator indicating the name of the individual to be issued a key.

Before keys are issued to an individual they must first sign a form acknowledging the keys that they have received and that they are liable for lock re-keying/replacement in the event a given key is lost.

For safety and liability reasons, **keys may not be shared with students or with other individuals; there are no exceptions to this rule.**

3.5.3. Buddy System

For safety reasons, no user can work in the lab alone after 5:00 pm on weekdays or at any time during the weekends.

Any user found in the cleanroom alone after hours will be banned from using the facility ever again. There are no second chances.

A “buddy” is defined as another individual who has undergone the HiDEC orientation session and thus knows the appropriate procedures to take in the event of an emergency. It is the responsibility of each user to check and see if they are the last person in the area.

If a user’s departure from the lab would result in another lab user being left alone, the person intending to leave should give the last person fair notice of their intent to leave **BEFORE** they intend to do so, so that the other user has time to shutdown tools or complete their activity.

3.5.4. Tour policy

Due to the sometimes sensitive nature of the research in Center facilities and to avoid possible interference with equipment installation or facility repairs, all tours must be cleared and supervised by the Director or (in his absence) a HiDEC staff member. If at all possible, at least 24 hours of notice should be given before the scheduled event. Tours should be arranged with a HiDEC staff member or through the office of the Director.