Facilities, Equipment and Other Resources – Georgia Institute of Technology Site

Georgia Tech offers robust research and educational programs in composites, with diverse expertise spanning materials chemistry, processing, manufacturing, design/modeling, mechanics, and testing. *Composites Structures Manufacturing and Maintenance* is one of six core areas of focus for the Georgia Tech Manufacturing Institute (GTMI), a university-level interdisciplinary research institute where the proposed CHMI Center will be housed. GTMI focuses on the complete innovation value chain – from raw and recycled resources to prototypes and finished products – and develops materials, systems, processes, education, and even policies that impact manufacturers' performance in the marketplace. With over 120,000 sq. ft. of dedicated lab and office space, GTMI houses many interdisciplinary researchers (including over 50 GT faculty members) and their teams in advanced manufacturing fields. The Institute has a comprehensive set of facilities and equipment for composite materials characterization, processing/ fabrication, NDE, testing, and computation and design available for use by the proposed CHMI Center.

Two of the most GTMI relevant labs include the *Composites and Nanocomposites Processing Lab (CNPL)* and the *Composite Joining and Repair Lab (CJARL).* CNPL houses comprehensive equipment for composite and nanocomposite processing, including VARTM composite processing stations, a thermal forming machine, CNT dispersion stations, CNT composite processing stations, a four-point probe electrical resistance tester, a NETZSCH Laser flash test station, TA ARES rheometer and viscometers, TA thermal analysis set (DMA/DSC/TGA), micro-indentation tester, and vacuum ovens. CJARL has state-of-the-art equipment and instruments for conducting CHMI research. The major equipment and tools include a Tentec Plasma surface treatment station, a Surface Analyst® surface analyzer, an Agilent FTIR surface analyzer, a surface profiler, a phased-array ultrasound NDI system, a Dantec DIC system, a Heatcon controlled curing station, Non-contact 3D scanning systems, an Optomec AJP 300 printer, a Fujifilm inkjet printer, a Xenon photonic sintering station, various ovens, a Heatcon Repair-clave, Hot Bonder, Vacuum Debulking, and a composite fabrication filtration table.

In addition to GTMI, most of the GT site faculty are also affiliated with the GT Institute for Materials (IMat), which provides access to state-of-the-art synthesis/processing, characterization and testing equipment for polymeric materials, metals, electronics materials and composites. Through IMat, researchers have access to the Carbon and Multi-functional Fiber Center, a prototyping center that utilizes gel spinning technology of PAN and PAN/CNT fibers in an effort to produce the next generation carbon fiber and highly specialized experimental fiber production equipment. Additionally, researchers have access to the Mechanical Properties Characterization Facility (MPCF), where principal activities are directed towards the measurement and modeling of the mechanical properties of engineering materials. Specifically, the MPCF specializes in materials studies related to deformation, fatigue, and fracture. The MPCF houses servohydraulic, electromechanical, creep, impact, fretting and reciprocating testing stations. Further, GT Site researchers also have access to the GT Materials Characterization Facility (MCF), a campus-wide shared facility formed in 2015. MCF offers a wide variety of microscopy and characterization tools, including SEM, FIB, TEM, XPS, Raman, FTIR, TGA, AFM, STM, and XRD. MCF has five SEMs, four of which (the FEI Nova, LEO1530, Hitachi SU8230 and Zeiss Ultra 60) are equipped with EDS and five TEMs, including JEOL 100CX, Hitachi HT7700, FEI Tecnai F30 or Hitachi HD2700. MCF also has a range of material surface and structure characterization tools, including several AFMs, Confocal Raman Microscope, Keyence VHX-600 Digital Microscope, and Hysitron Triboindentor.

Beyond the state-of-the-art facilities and equipment available through GTMI and IMat, the GT Site faculty and researchers also have access to additional state-of-the-art facilities and equipment in various laboratories of affiliated academic units on the GT campus. Specifically, for characterization of materials chemistry and structure, the GT Site faculty has access to equipment such as NMR, IR spectroscopy, UV/Vis spectroscopy, X-ray diffraction, XPS, X-ray tomography, and micro-CT. The GT Site faculty and researchers further unite various computational capabilities in CAD, CAE, data analytics and modeling through software like Abaqus®, ANSYS®, Biovia® Material Studio, COMSOL®, and MATLAB®, as well as in- house faculty developed codes. The Aerospace Systems Design Laboratory (ASDL) in the School of Aerospace Engineering, with high-performance computing and visualization facilities, is also available for GT Site researchers to conduct CHMI design and analysis research. The high-performance computing cluster includes Penguin Computing Relion 1900 and 2940 Servers, Penguin Computing IceBreaker 4924 storage node, and Intel True Scale 12300 interconnect. The Collaborative Visualization Environment (CoVE) in ASDL provides researchers with the capability to present detailed and complex analysis results on a very large visualization real estate that offers a rich and interactive visualization experience.

Facilities, Equipment, and Other Resources – Oakland University Site

Oakland University has unique research and education programs in the field of material fastening and joining, with diverse expertise in mechanics, analysis, modeling and simulation, chemical analysis, testing and validation, process engineering, automation and control, and data analytics. Since their establishment at OU in 2003, the material joining research labs have attracted more than $14 million in external funding from federal and Industrial sources such as the US Army Ground Vehicle and Systems Center (GVSC), General Dynamics, GM, Ford, Chrysler, John Deere, Big Three automotive OEMs, John Deere, and NSF-SBIR. The fastening and joining research labs at OU have recently contributed to the development of NASA standards for the US Space Flight Hardware (NASA-STD-5020). A comprehensive set of state-of-the-art equipment and facilities for material joining research and technology innovation includes: computational modeling and simulation labs, surface treatment and inspection, process control and automation, and materials, mechanical, and environmental testing, NDE/NDI, and specialized labs for material Joining. Several other support labs from departments (e.g. materials, machining, chemistry, physics, etc.) are also available for material joining research.

A. Material Joining and Testing

1. **Computer-Controlled Autoclave**
   The Autoclave is used for making small transparent armor samples for research purposes following ASTM standard tests at the fastening and joining labs-OU. It also has the capacity for making limited TA panels for exponential performance testing after environmental cycling.
2. **DMA Q800**
   The DMA Q800 is used to study the dynamic properties of polymers.
3. **Thermotron SE-300-6-6 Temperature-humidity test chamber, with UV controls**
4. **Two Computer-Controlled RS Torque-Tension Systems**
   (1) up to 280 ft.lb torque, and (2) up to 1000 ft.lb torque
   Various automatic control methods may be programmed. The Systems also evaluates fastener coatings by measuring the thread friction coefficient, as well as the bearing friction coefficient.
5. **Veeco WYKO NT1100 optical profiler/microscope**
6. **MTS 810 Fatigue Testing System (100kN capacity, 70 HZ)**
   The system can do different quasi-static tension/compression tests and cyclic fatigue tests for different samples under different load waveforms. The load capacity is 100kN. The highest frequency under cyclic loading is 70Hz.
7. **MTS 810 Fatigue Testing System (250kN capacity, 70 HZ)**
   The system can do different quasi-static tension and compression tests and cyclic fatigue tests for different samples under different load waveforms. The load capacity is 250kN. The highest frequency under cyclic loading is 70Hz.
8. **RDO Induction HFI 3.0 kW RF Heating System with Custom Copper Coil**
   Water cooled induction heating system, with custom coil tailored for reversible adhesives application. The system's maximum power is 3 kW, and operates in the 135-400 kHz frequency range.
9. **Cyclic Corrosion Chamber**
   Designed to meet ASTM, SAE, and most all other automotive test for cyclic corrosion testing such as CCT1, 2, 3, 4, 9540P, SAE J2334 and more. This chamber is capable of performing ASTM G85 Modified Salt Spray (fog) Testing, Annex A5 Dilute Electrolyte Cyclic salt Spray (fog) Testing, ASTM B117 (Salt fog), ASTM G85, Mil-Std- 883, Method 1009.5, B368 (CASS), Mil Std 810D, Method 509.2.

10. **Ultrasonic Testing Equipment MC900 Transient Record Analyzer**
    The MC900 Ultrasonic Testing Equipment is used to evaluate bolt load, measured by monitoring the fastener elongation under axial load.
11. **Kruss DSA 25 Drop Shape Analyzer**
    The Kruss Drop Shape Analyzer is used to evaluate the Surface Free Energy of metallic and non-metallic materials. It deposits a drop of a polar and nonpolar test liquid on the substrate, while measuring the static and dynamic contact angles.
12. **APEX multi-spindle partner tool**
    5 spindles with independent linear drivers, simultaneous torque-angle-speed control.
13. **Junker Testing Machine**
    Custom-built, for vibration loosening analysis of threaded fasteners.

B. Materials Characterization

The School of Engineering and Computer Science houses a complete materials lab that includes equipment for mechanical testing, metallographic sample preparation, and materials characterization. Mechanical test equipment includes macro and microhardness testers, two tensile test machines (20kN and 50kN capacity), and a Charpy impact tester for polymers and composites. The lab has a cut-off saw, a belt grinders, diamond saw for precision sectioning, and polishing and etching stations for metallographic sample preparation. For optical inspection and microstructural characterization the materials lab has an inverted optical metallograph and stereo optical microscope. The school also has an Advanced Materials Characterization Suite with two scanning electron microscopes (SEM) with energy dispersive spectroscopy (EDS) for elemental analysis, an X-ray photoelectron spectrometer (XPS) for surface characterization. Also housed in the lab is a nanoindenter. A transmission electron microscope (TEM) with associated sample preparation tools will soon be installed. Purchase of one of the SEMs and the TEM were funded through NSF Major Research Instrument grants.

C. Non-Destructive Techniques/Evaluation

The NDT/NDE labs are consist of four laboratories (1,600 Sq. Ft.): Optical measurement and Quality Inspection Lab, Digital Shearography Lab, Digital Holographic Application Lab, and Strain/Stress Measurement Lab. The focus of the research in these laboratories is NDT/NDE and strain/stress measurement for advanced materials, particularly, for composite materials. Routine laboratory equipment includes various optical components, vibration isolation tables, piezoelectric actuators, vibration shakers etc.

Special instruments for NDT/NDE and Strain/Stress Measurement include:

1. Two digital shearographic sensors: one from Dantec Dynamics (Q800), Germany, and another one specially developed by the optical lab of Oakland University for NDT under dynamic loading.
2. Two 3D digital holographic sensors, both from Dantec Dynamics, Germany, one (Q300) with a measuring sensitivity of 30 nm, and another (Q100) with a measuring sensitivity of 10 micro strain, which enable to measure sub-micrometer deformation and micro strain.
3. Four 3D Digital Image Correlation (DIC) Systems, all from Dantec Dynamics, Germany, for measuring strain under different conditions, such as high speed, high temperature, high pressures.
    - ***The first one*** is a standard 3D DIC system, capable of measuring strain from 50 micro strain to a few percent from very small areas (down to 1 square mm) to regular measurement areas (about 300x300 square mm) by using different lenses
    - ***The second one*** is a high speed DIC system, up to 5000 fps.
    - ***The third one*** is an 8 cameras DIC system that enables to measure strain on large objects or on a 360° range.

- ***The last one*** is the newly developed multi camera DIC system that enables to measure true 3D strains, including strain in thickness direction.

D. Chemistry

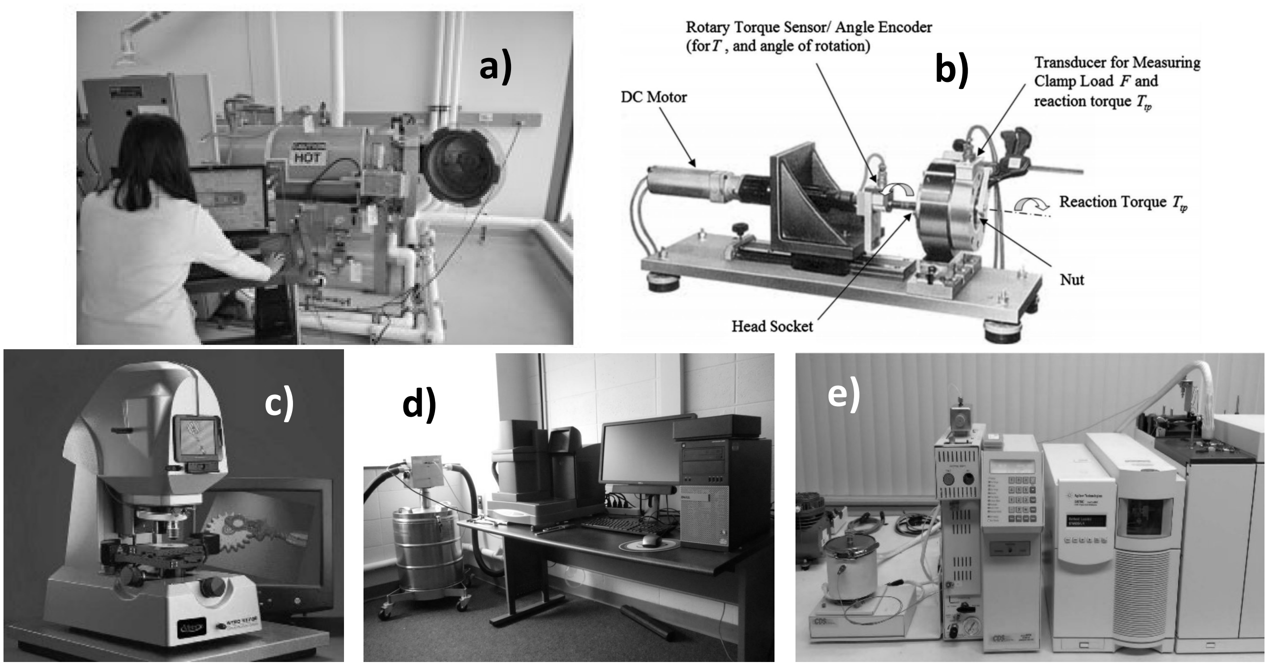
Core Equipment: Equipment available in the Oakland University Chemistry Department

- NMR Spectrometers
- UV-vis Spectrometers
- Gas Chromatographs
- Liquid Chromatographs
- Solvent Purification
- IR Spectrometers
- Radiochemistry Equipment (Laser Irradiation, Liquid Scintillation, Gamma Counter)
- Atomic Absorption/Emission Spectrometers
- Electrochemical Instrumentation (Impedance Analyzer, Potentiostats)
- Electrophoresis Equipment
- Centrifuges
- Surface Plasmon Resonance Spectrometer
- Fluorescence/Chemiluminescence Equipment (luminometer, photomultiplier)

E. CAE Labs

Software, Mathematical, and FEA Simulation Capabilities at the material joining labs-OU:

- ABAQUS, FEA Research suite
- Ansys
- Hyperworks
- nCode
- Catia
- Matlab
- Mathematica



Sample material joining research equipment at Oakland University (a. Autoclave bonding, b. Ultrasonically-controlled joining, c. Surface profiler, d. DMA, e. GCMS Gas Chromatography – Mass Spectrometry system

Facilities, Equipment and Other Resources – University of Tennessee Site

With respect to the CHMI IUCRC, the following assets/infrastructure is in place:

a) The UT facilities namely - Fibers and Composites Manufacturing Facility (FCMF) at UT, Joint Institute for Advanced Materials (JIAM), Center for Renewable Carbon (CRC), Advanced Mechanical Characterization facility provide comprehensive equipment and assets for this Center.
   a. The integration of the UT with IACMI-The Composites Institute and Oak Ridge National Laboratory (Manufacturing Demonstration Facility (MDF) the world's largest Big Area Additive Manufacturing Facility with over 100,000 square feet of advanced materials & manufacturing R&D. All the IUCRC students, staff, researchers, and industry partners are integrated with this facility.
   b. Carbon Fiber Technology Facility (CFTF)) provide unparalleled ecosystem for all aspects of the R&D. Currently IACMI has over 160 member companies in the area of advanced composites- ranging from material suppliers, Tiers, OEMs, organizations, national labs and academic institutions.
   c. UT is part of the East Tennessee Composites Coalition, an entity comprising over 50 companies/industries focused on advanced composites technologies and applications.

b) 18" and 12" sheet molding compounding (SMC) line, 3.5" plasticator for long carbon, glass, natural fiber extrusion-compression.
c) 100-, 150- and 500-ton compression presses; Beckwood, Wabash, and Tinker.
d) RocTool Induction Heating set up for rapid tool heating/forming/joining.
e) Open air Plasmatreat system for surface preparation.
f) 36" conveying oven up to 1000 F temperature capability.
g) Thwing-Albert wet laid set up for RCF and TCF fiber mats production.
h) Pultrusion line and roll forming line for in-line joining of continuous fiber composites.
i) RTM and VARTM MVP metering, mixing, and dispensing.
j) Full suite of NDE – 4 channel Mistras acoustic emission, Olympus phase array ultrasonic system; Bruel & Kjaer vibration Pulse Analyzer/Shaker.
k) Thermal Digital Image Correlation.
l) Test frame for joint testing (Test Resources).
m) 3DS Experience (Dassault Systems), Autodesk Inventor, SolidWorks, AlphaStar Genoa/MCQ, ANSYS, Abaqus, Moldflow 3D, NextruCAD and esi suite software for CAD, process, and structural modeling.
n) ODiSI 6000 and ODiSIB Series sensing platforms for integrating into composite manufacturing process control and smart joining technology, collecting strain and temperature data with exceptional spatial and targeted time resolution.
o) Fabricate and integrate low-cost fiber optic sensors using standard telecommunication grade optical fiber and related splicing and joining resources.
p) Extensive mechanical servo-hydraulic testing systems from MTS (810 and 858 multiple systems) for mechanical characterization.
q) FLIR thermal camera system with high spatial and temperature resolution.
r) VIC 3D and ARAMIS 3D Digital Image Correlation Systems.
s) LASIS-GRR set-up equipped with a high-energy Nd:YAG laser (1064 nm/ 532 nm wavelengths; 135-330 mJ/pulse energy).
t) In-house fabricated ablation cell.
u) Glove box with controlled atmosphere.
v) LIBS set-up.
w) Scanning mobility particle sizer (SMPS).
x) Spectroscopic ellipsometry.

y) Scanning probe and tunneling microscopy (AFM/STM).
z) Tabletop comprehensive processing demos for extrusion, filamenting, shredding, injection molding, and 3D printing.
aa) Blow molding station for PET and common plastic.
bb) Trelleborg Automated Tape Placement (ATP) machine, ¼”-1” tapes.
cc) Mclean Anderson filament winding machine with mandrel size control – 18’.
dd) HAAS vm-3 machining center.
ee) Freeform Kuka robot machining cell with automatic tools changing spindle.
ff) Joining cell station for adhesive joining.
gg) Motor/dyno top 8250 instrumented impact drop tower.
hh) PMP Porosimeter for measurement of pore size.
ii) 3D Additive manufacturing for printing PEEK, PEI, PPS, PEKK, PSU, PPSU.