FACILITIES

In addition to the facilities of the individual team members, the proposed DARPA center will strongly benefit from existing and planned research centers at the Georgia Institute of Technology. In the following, we will give an overview of the main research facilities in the area of micro- and nanomanufacturing:

Microelectronics Research Center (MiRC), http://www.mirc.gatech.edu: The MiRC is housed in its own 100,000 sq.ft. building that includes an 8,500 sq.ft. cleanroom (75% class 100, 25% class 10). Georgia Tech is a member of the National Nanotechnology Infrastructure Network (NNIN) with much of the GT-NNIN activity carried out in the MiRC. The major fabrication tools in the MiRC cleanroom include: Electron Beam Lithography (100 keV / 4nm spot size JEOL JBX 9300FS), Plasma Enhanced Chemical Vapor Deposition, Electron Beam Evaporator, Filament Evaporator, Programmable Rapid Thermal Processor, Scanning Electron Microscope, Auto-load and Manual Spin Coater, Spin Develop Station, Mask Aligner/UV Exposure Tool, Automated Dicing Saw, Polishing and Lapping Stations, Wire Bonders (Au, Cu, Al), Dark Room Facility for Mask Generation, RF & DC Magnetron Sputtering Systems, Reactive Ion Etching Chambers, Electroplating, Flip-Chip Bonder, III-V MBE growth, and a 2-metal/2-poly CMOS and MEMS line (ion implantation outsourced). Characterization tools available at MiRC include: optical and electron microscopy, AFM, SCM, STM, stylus and optical profilometry, low/high force scanning nanoindentation tribology, surface analysis tools, and high speed electronic and optical testing.

Center for Nanostructure Characterization and Fabrication (CNCF), http://cncf.nanoscience.gatech .edu: The CNCF hosts the following major characterization and fabrication tools: a 200 keV Hitachi HF-2000 field emission gun (FEG) transmission electron microscope (this microscope is one of the few instruments in the United States capable of performing high spatial-resolution chemical microanalysis, high-resolution lattice imaging and high-coherent beam holographic imaging and was purchased with a equal investment of $1.5M by the National Science Foundation and the State of Georgia); a JEOL 4000EX HREM (400 kV), which routinely gives a point-to-point image resolution of 1.8 Å and is best suited for recording high-resolution images of thin foil specimens (this instrument is ideally suited for characterization of catalysts); a JEOL 100CX II (120 kV) for conventional research and educations (this TEM operates at voltages of 40, 60, 80 kV to 120 kV, and it is ideally suitable for imaging biological specimens); a Hitachi S800 FEG scanning electron microscopy (SEM), which can be used to image the morphology of materials at a resolution better than 30 Å and to perform chemical microanalysis from bulk specimens; a state-of-the-art FEG SEM LEO 1530 (this SEM has an 1 nm resolution at 20 kV and 3 nm resolution at 1 kV and is equipped with EDS and backscattering electron diffraction; it is ideally suited for characterization of nanophase materials and fully equipped for chemical mapping, orientational imaging and structure analysis); a state-of-the-art FEG SEM LEO 1550 SEM with e-beam lithography facility; two FEI Focused Ion Beam microscopes for nano fabrications; a Digital Instruments STM/AFM system for nano-scale measurements and manipulation; TEM specimen preparation facility including two ion-milling machines, polishing, grinding and dimpling equipment; image simulation and processing facility including two Macintosh PowerPC computers and a Silicon graphics computer; a Gatan single tilt specimen heating holder up to a temperature of 1300 ^{o}C for in-situ TEM studies of phase transformation; CVD processes based on tube furnace (Thermolyne 59300 tube furnace (1700 C), Thermolyne 79300 tube furnace (1300 C)) for synthesis of nanowire and nanobelts; three high-temperature tube furnaces for growth of nanobelts of oxides; laser ablation system; UV luminance spectrometer; AFM manipulator.

Packaging Research Center (PRC), http://www.prc.gatech.edu: The PRC was established in 1994 with more than $5 million annual funding from NSF, the State of Georgia, and member companies. The PRC facilities include test bed research labs, an electrical design lab, a system-on-a-package substrate lab with a class 1,000 cleanroom, and a system-on-a-package module and reliability lab. The Packaging Research Center has access to the following Microfabrication equipment: Plasma enhanced chemical vapor deposition, electron beam evaporator, filament evaporator, programmable rapid thermal processor, scanning electron microscope, auto-load and manual spin coater, spin develop station, mask aligner/UV exposure tool, automated dicing saw, polishing and lapping stations, wire bonders (Au, Cu and Al), dark room facility for mask generation, RF and DC magnetron sputtering systems and Reactive ion etch chambers.

Nanotechnology Research Center, http://www.nano.gatech.edu: A new 160,000 sq.ft. building with 30,000 sq.ft. of cleanroom space to host this center is in the planning stage and is expected to be completed in 2008.

Mechanical Properties Research Laboratory (MPRL), http://www.me.gatech.edu/mprl: Tensile and fatigue test facility, high temperature high vacuum test facility, thermal aging facility, creep testing facility, x-ray diffraction lab, microtester system, nanoUTM and nano-indenter DCM.

School of Chemistry and Biochemistry Labs: For the characterization of nanoparticles, the labs have the following equipment: Bruker D8 Advance powder X-ray diffractometer, Quantum Design MPMS-5S SQUID magnetometer, Austin Science Mössbauer spectrometer. In addition, the investigators have access to the following equipment: a Micromeritics ASAP 2000 instrument for BET surface area measurements, several UV-Vis spectrometer of various brands and models, an IR spectrometer equipped with surface-acoustic capability, an ICP-AES, two TGAs and two DSCs, an FACS Vantage SE Flow Cytometer, and a Zeiss LSM 510 confocal microscope equipped with an Argon laser.

The following table finally lists part of the additional equipment available through the center members:

NANO STRUCTURED MATERIALS
Chemical vapor deposition (CVD) furnace dedicated to the production of CNT-based materials and an Olympus PM-10AD microscope system (1000X). PANalytical X-ray diffractometer. Nanotube synthesis apparata (total capacity ~ 1.5 L) and a purification apparatus. Bruker IR spectrometer and reflectometer. Two Thomas Swan Close-Coupled Showerhead MOCVD Reactors for III-N growth with LayTec EpiTT emissivity-corrected pyrometer and optical reflectance systems. JEOL Model 6300FE Field-Emission SEM with an Oxford Instruments/Gatan MonoCL2 upgraded variable-temperature (4-300K) cathodoluminescence system. Accent Optical Model 4400 Electrochemical Profiler. Accent Optical PL Wafer mapping system. Accent Optical computer-controlled Hall-effect system. Philips X'pert X-ray high-resolution triple-axis diffraction system. Reichert Nomarski optical microscope. Various spectrometers and computer-controlled PL and EL data acquisition systems. Variable-temperature Oxford Opitstat optical dewar system. *I-V* and *C-V* measurement systems: Hewlett-Packard Model 4142B high-power modular device characterization system; Agilent 4156C Semiconductor Parameter Analyzer; Karl Süss MA-6 Probe Station with ultra-low-leakage probes.
NANO INTEGRATION
A 75-ton Injection Molding Machine (SHI Plastics Machinery, model SG-75). Variable thickness mold for IMM (MUD Systems, Inc.). Mold Heater for IMM (Delta-T Systems). Mini-Reaction Injection Molding Machine (computer controlled). Ultrasonic C-scanner (Physical Acoustics, model UltraPak II, computer controlled, color output). Modulated Differential Scanning Calorimeter (TA Instruments, model 2920, modulated, with Photocalorimeter).; Dynamic Mechanical Analyzer (TA Instruments, model 2980, modulated). Computer controlled extruder and attachments (twin-screw, single-screw, mixer, dies) (Brabender, Haake-Buchler Model 40). Filament Winder (Entec, model PW18WX-036-2). Resin Transfer Molding Machine (Liquid Control). 50-ton Vacuum Hot Press (Wabash, model V50-1818-2TMX). Nitrogen Purge Oven. Vacuum ovens.
NANO SYSTEM TEST AND RELIABLITY
Solatron 1260 impedance analyzer, Solatron 1286 potentiostat, CHE Biopotentiostat, 617 Keithley electrometer, Keithley 195A nanovoltmeter, twenty channel HP3970A DVM, Stanford Research Systems lock-in amplifiers, HP oscilloscope and four channel Tektronics Oscilloscope. Gas mixing and handling system. Inverted microscope, Nikon Eclipse TE2000-S with image processing software customized built flow characterization and pressure measurement instrumentation.

Through these existing and planned facilities, the center members (a) have access to a unique and expensive micro/nanomanufacturing tool set, (b) perform prototyping and small volume manufacturing, (c) provide contract services for single step processes or services, and (e) provide hands-on educational programs for academia and industry.