AIR FORCE
STTR 08.B PROPOSAL PREPARATION INSTRUCTIONS

The Air Force proposal submission instructions are intended to clarify the DoD instructions as they apply to AF requirements.

The responsibility for the implementation and management of the Air Force Small Business Technology Transfer (STTR) Program is with the Air Force Research Lab, Wright-Patterson Air Force Base, Ohio. The Air Force STTR Program Manager is Mr. Steve Guilfoos, (800) 222-0336. The Air Force Office of Scientific Research (AFOSR) is responsible for scientific oversight and program execution of Air Force STTRs.

Air Force Research Laboratory
AFOSR/PIE
Attn: Raheem Lawal
875 Randolph Street
Suite 325, Room 3112
Arlington, VA 22203-1954

Phone: (703) 696-7313 / (703) 696-9513
Fax: (703) 696-7320
Email: raheem.lawal@afosr.af.mil

For general inquires or problems with the electronic submission, contact the DoD Help Desk at 1-866-724-7457 (8:00 am to 5:00 pm EST). For technical questions about the topic during the pre-solicitation period (28 July through 24 August 2008), contact the Topic Authors listed for each topic on the website. For information on obtaining answers to your technical questions during the formal solicitation period (25 August through 24 September 2008), go to http://www.dodsbir.net/sitis.

The Air Force STTR Program is a mission-oriented program that integrates the needs and requirements of the Air Force through R&D topics that have military and commercial potential.

Unless otherwise stated in the topic, Phase I will show the concept feasibility and Phase II will produce a prototype or at least show a proof-of-principle.

Phase I period of performance is typically 9 months, not to exceed $100,000.

Phase II period of performance is typically 2 years, not to exceed $750,000.

The solicitation closing dates and times are firm.

PHASE I PROPOSAL SUBMISSION

Read the DoD program solicitation at www.dodsbir.net/solicitation for detailed instructions on proposal format and program requirements. When you prepare your proposal, keep in mind that Phase I should address the feasibility of a solution to the topic. For the Air Force, the contract period of performance for Phase I shall be nine (9) months, and the award shall not exceed $100,000. We will accept only one cost proposal per topic proposal and it must address the entire nine-month contract period of performance.

The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each Air Force organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and review by the Air Force Technical point of contact utilizing the criteria in section 4.3 of the DoD solicitation The last three months of the nine-month Phase I contract will provide project continuity for all Phase II award winners so no modification to the Phase I contract should be necessary. **Phase I technical proposals have a 20 page-limit (excluding the cost proposal and Company Commercialization Report).** The Air Force will evaluate and select Phase I proposals using review criteria based upon technical merit, principal investigator qualifications, and commercialization potential as discussed in this solicitation document.

ALL PROPOSAL SUBMISSIONS TO THE AIR FORCE MUST BE SUBMITTED ELECTRONICALLY.

It is mandatory that the complete proposal submission -- DoD Proposal Cover Sheet, **ENTIRE** Technical Proposal with any appendices, Cost Proposal, and the Company Commercialization Report -- be submitted electronically through the DoD SBIR/STTR website at http://www.dodsbir.net/submission. Each of these documents is to be submitted separately through the website. Your complete proposal **must** be submitted via the submissions site on or before the **6:00 am EST 24 September 2008** deadline. A hardcopy **will not** be accepted. Signatures are not required at proposal submission when submitting electronically. If you have any questions or problems with electronic submission, contact the DoD SBIR/STTR Help Desk at 1-866-724-7457 (8am to 5pm EST).

Acceptable Format for On-Line Submission: The technical proposal should include all graphics and attachments but should not include the Cover Sheet or Company Commercialization Report (as these items are completed separately). Cost Proposal information should be provided by completing the on-line Cost Proposal form.

Technical Proposals should conform to the limitations on margins and number of pages specified in the front section of this DoD solicitation. However, your cost proposal will only count as one page and your Cover Sheet will only count as two, no matter how they print out after being converted. Most proposals will be printed out on black and white printers so make sure all graphics are distinguishable in black and white. It is strongly encouraged that you perform a virus check on each submission to avoid complications or delays in submitting your Technical Proposal. To verify that your proposal has been received, click on the "Check Upload" icon to view your proposal. Typically, your uploaded file will be virus checked and converted to PDF within the hour. However, if your proposal does not appear after an hour, please contact the DoD SBIR/STTR Help Desk.

The Air Force recommends that you complete your submission early, as computer traffic gets heavy near the solicitation closing and slows down the system. **Do not wait until the last minute.** The Air Force will not be responsible for proposals being denied due to servers being "down" or inaccessible. Please assure that your e-mail address listed in your proposal is current and accurate. By the end of September, you will receive an e-mail serving as our acknowledgement that we have received your proposal. The Air Force cannot be responsible for notifying companies that change their mailing address, their e-mail address, or company official after proposal submission.

COMMERCIAL POTENTIAL EVIDENCE

An offeror needs to document their Phase I or II proposal's commercial potential as follows: 1) the small business concern's record of commercializing STTR or other research, particularly as reflected in its Company Commercialization Report http://www.dodsbir.net/submission; 2) the existence of second phase funding commitments from private sector or non-STTR funding sources; 3) the existence of third phase follow-on commitments for the subject of the research and 4) the presence of other indicators of commercial potential of the idea, including the small business' commercialization strategy.

ELECTRONIC SUBMISSION OF PROPOSAL

If you have never visited the site before, you must first register your firm and create a password for access (Have your Tax ID handy). Once registered, from the Main Menu:

Select "Prepare/Edit Phase I Cover Sheets" –

1. **Prepare a Cover Sheet.** Add a cover sheet for each proposal you plan to submit. Once you have entered all the necessary cover sheet data and clicked the Save button, the proposal grid will show the cover sheet you have just created. You may edit the cover sheet at any time prior to the close of the solicitation.
2. **Prepare a Cost Proposal.** Use the on-line proposal form by clicking on the dollar sign icon.
3. **Prepare and Upload a Technical Proposal.** Using a word processor, prepare a technical proposal following the instructions and requirements outlined in the solicitation. When you are ready to submit your proposal, click the on-line icon to begin the upload process. You are responsible for virus checking your technical proposal file prior to upload. Any files received with viruses will be deleted immediately.

Select "Prepare/Edit a Company Commercialization Report" –

4. **Prepare a Company Commercialization Report.** Add and/or update sales and investment information on all prior Phase II awards won by your firm.

NOTE: Even if your company has had no previous Phase I or II awards, you must submit a Company Commercialization Report. Your proposal will not be penalized in the evaluation process if your company has never had any STTR Phase Is or IIs in the past.

Once steps 1 through 4 are done, the electronic submission process is complete.

AIR FORCE PROPOSAL EVALUATIONS

Evaluation of the primary research effort and the proposal will be based on the scientific review criteria factors (i.e., technical merit, principal investigator (and team), and commercialization plan). Please note that where technical evaluations are essentially equal in merit, and as cost and/or price is a substantial factor, cost to the government will be considered in determining the successful offeror. The Air Force anticipates that pricing will be based on adequate price competition. The next tie-breaker on essentially equal proposals will be the inclusion of manufacturing technology considerations.

The Air Force will utilize the Phase I evaluation criteria in section 4.2 of the DoD solicitation in descending order of importance with technical merit being most important, followed by the qualifications of the principal investigator (and team), and followed by commercialization plan. The Air Force will use the phase II evaluation criteria in section 4.3 of the DoD solicitation with technical merit being most important, followed by the commercialization plan, and then qualifications of the principal investigator (and team).

PROPOSAL/AWARD INQUIRIES

We anticipate having all the proposals evaluated and our Phase I contract decisions within approximately four months after proposal receipt. All questions concerning the evaluation and selection process should be directed to the Air Force Office of Scientific Research (AFOSR).

ON-LINE PROPOSAL STATUS AND DEBRIEFINGS

The Air Force has implemented on-line proposal status updates and debriefings (for proposals not selected for an Air Force award) for small businesses submitting proposals against Air Force topics. At the close of the Phase I Solicitation – and following the submission of a Phase II via the DoD SBIR / STTR Submission Site (https://www.dodsbir.net/submission) - small business can track the progress of their proposal submission by logging into the Small Business Area of the Air Force SBIR / STTR Virtual Shopping Mall (http://www.sbirsttrmall.com). The Small Business Area (http://www.sbirsttrmall.com/Firm/login.aspx) is password protected and uses the same login information as the DoD SBIR / STTR Submission Site. Small Businesses can view information for their company only.

To receive a status update of a proposal submission, click the "Proposal Status / Debriefings" link at the top of the page in the Small Business Area (after logging in). A listing of proposal submissions to the Air Force within the last 12 months is displayed. Status update intervals are: Proposal Received, Evaluation Started, Evaluation Completed, Selection Started, and Selection Completed. A date will be displayed in the appropriate column indicating when this stage has been completed. If no date is present, the proposal submission has not completed this stage. Small businesses are encouraged to check this site often as it is updated in real - time and provide the most up - to- date information available for all proposal submissions**. Once the "Selection Completed" date is visible, it could still be a few weeks (or more) before you are contacted by the Air Force with a notification of selection or non – selection.** The Air Force receives thousands of proposals during each solicitation and the notification process requires specific steps to be completed prior to a Contracting Officer distributing this information to small business.

The Principal Investigator (PI) and Corporate Official (CO) indicated on the Proposal Coversheet will be notified by Email regarding proposal selection or non-selection. The Email will include a link to a secure Internet page to be accessed which contains the appropriate information. If your proposal is tentatively selected to receive an Air Force award, the PI and CO will receive a single notification. If your proposal is not selected for an Air Force award, the PI and CO may receive up to two messages. The first message will notify the small business that the proposal has not been selected for an Air Force award and provide information regarding the availability of a proposal debriefing. The notification will either indicate that the debriefing is ready for review and include instructions to proceed to the "Proposal Status / Debriefings" area of the Air Force SBIR / STTR Virtual Shopping Mall or it may state that the debriefing is not currently available but generally will be within 90 days (due to unforeseen circumstances, some debriefings may be delayed beyond the nominal 90 days). If the initial notification indicates the debriefing will be available generally within 90 days, the PI and CO will receive a follow – up notification once the debriefing is available on-line. All proposals not selected for an Air Force award will have an on-line debriefing available for review. Available debriefings can be viewed by clicking on the

"Debriefing" link, located on the right of the Proposal Title, in the "Proposal Status / Debriefings" section of the Small Business Area of the Air Force SBIR / STTR Virtual Shopping Mall**. Small Businesses will receive a notification for each proposal submitted. Please read each notification carefully and note the proposal number and topic number referenced. Also observe the status of the debriefing as availability may differ between submissions (e.g., one may state the debriefing is currently available while another may indicate the debriefing will be available within 90 days).**

PHASE II PROPOSAL SUBMISSIONS

Phase II is the demonstration of the technology that was found feasible in Phase I. Only those Phase I awardees that are **invited** to submit a Phase II proposal and all FAST TRACK applicants will be eligible to submit a Phase II proposal. The Phase I award winners must accomplish the majority of their primary research during the first six months of the contract. Each Air Force organization may request Phase II proposals prior to the completion of the first six months of the contract based upon an evaluation of the contractor's technical progress and reviewed by the Air Force Technical point of contact utilizing the criteria in section 4.3 of the DoD solicitation The awarding Air Force organization will send detailed Phase II proposal instructions to the appropriate small businesses. Phase II efforts are typically two (2) years in duration and do not exceed $750,000. (NOTE) All Phase II awardees must have a Defense Contract Audit Agency (DCAA) approved accounting system**. Get your DCAA accounting system in place prior to the AF Phase II award timeframe. If you do not have a DCAA approved accounting system this will delay / prevent Phase II contract award. If you have questions regarding this matter, please discuss with your Phase I contracting officer.**

All proposals must be submitted electronically at www.dodsbir.net/submission. The complete proposal **-** Department of Defense (DoD) cover sheet, entire technical proposal with appendices, cost proposal and the Company Commercialization Report – must be submitted by the date indicated in the invitation. The technical proposal is **limited to 50 pages** (unless a different number is specified in the invitation). The commercialization report, any advocacy letters, and the additional cost proposal itemized listing (a through h) will not count against the 50 page limitation and should be placed as the last pages of the Technical Proposal file that is uploaded. (Note: Only one file can be uploaded to the DoD Submission Site. Ensure that this single file includes your complete Technical Proposal and the additional cost proposal information.) The preferred format for submission of proposals is Portable Document Format (PDF). Graphics must be distinguishable in black and white. **Please virus check your submissions**.

FAST TRACK

Detailed instructions on the Air Force Phase II program and notification of the opportunity to submit a FAST TRACK application will be forwarded with all AF Phase I selection E-Mail notifications. The Air Force encourages businesses to consider a FAST TRACK application when they can attract outside funding and the technology is mature enough to be ready for application following successful completion of the Phase II contract.

NOTE:

1. Fast Track applications must be submitted not later than 150 days after the start of the Phase I contract.
2. Fast Track Phase II proposals must be submitted not later than 180 days after the start of the Phase I contract.
3. The Air Force does not provide interim funding for Fast Track applications. If selected for a Phase II award, we will match only the outside funding for Phase II.

For FAST TRACK applicants, should the outside funding not become available by the time designated by the awarding Air Force activity, the offeror will not be considered for any Phase II award. FAST TRACK applicants may submit a Phase II proposal prior to receiving a formal invitation letter. The Air Force will select Phase II winners based solely upon the merits of the proposal submitted, including FAST TRACK applicants.

PHASE II ENHANCEMENT POLICY

The Air Force currently does not participate in the DoD Enhancement Program.

PHASE I SUMMARY REPORTS

In addition to all the Phase I contractual deliverables, Phase I award winners must submit a Phase I Final Summary Report at the end of their Phase I project. The Phase I summary report is an unclassified, non-sensitive, and non-proprietary summation of Phase I results that is intended for public viewing on the Air Force SBIR / STTR Virtual Shopping Mall. A summary report should not exceed 700 words, and should include the technology description and anticipated applications / benefits for government and / or private sector use. It should require minimal work from the contractor because most of this information is required in the final technical report. The Phase I summary report shall be submitted in accordance with the format and instructions posted on the Virtual Shopping Mall website at http://www.sbirsttrmall.com.

SUBMISSION OF FINAL REPORTS

All final reports will be submitted to the awarding Air Force organization in accordance with Contract Data Requirements List (CDRL). Companies **will not** submit final reports directly to the Defense Technical Information Center (DTIC).

AIR FORCE STTR PROGRAM MANAGEMENT IMPROVEMENTS

The Air Force reserves the right to modify the Phase II submission requirements. Should the requirements change, all Phase I awardees that are invited to submit Phase II proposals will be notified. The Air Force also reserves the right to change any administrative procedures at any time that will improve management of the Air Force STTR Program.

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Air Force SBIR 08B Topic Descriptions

AF08-BT01 TITLE: Autonomous Nonbattery Wireless Strain Gage for Structural Health Testing and Monitoring in Extreme Environments

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a passive, conformal RF device capable of sensing and transmitting wide bandwidth strain or structural health monitoring data at service temperatures ranging from -60C to +300C.

DESCRIPTION: This topic seeks novel concepts for a passive, conformal sensor that can transmit high-bandwidth data from extreme environments at temperatures ranging from -60C to +300C and accelerations levels up to 56600g. The sensor should be easily installed with no permanent changes to the component or surface upon which it is installed. The sensor must be sufficiently small and conformal to avoid disrupting aerodynamic flows.

Situations arise with structural testing or structural health monitoring of aerospace components operating in extreme environments (jet engine fan and compressor blades, aircraft propellers, helicopter blades, transmission parts) where a passive sensor capable of transmitting high-bandwidth sensor data is needed. A common method of structural testing or structural health monitoring is to install sensors and wire them to a data collection system. For example, strain and shear are sensed with this technique. However, wired sensors are generally limited to temperate environments and stationary structures. In more difficult test environments, either a wired sensor cannot be installed or the sensor and its wires are expensive to install and short-lived. Further, powering a sensor with batteries is usually impractical and sometimes impossible, so a passive sensor is necessary. Bulky wireless data relay devices are available to condition and transmit sensor data, but they cannot be used in harsh environments, extreme temperatures, tight spaces, or fast-moving structures, and the sensors still need to be wired to the data relay.

PHASE I: Determine technical feasibility and an approach for the RF device. Feasibility must be addressed for operating temperature, strain sensing, high-rate data transmission, operation of multiple sensors on the same test article, and sensor size.

PHASE II: Fabricate and demonstrate the operation of a number of passive, conformal RF devices on a high speed, high temperature aerospace component. The operating environment includes temperatures up to 300C and acceleration forces up to 56600g.

PHASE III / DUAL USE: Military application: Conformal RF device is being developed for structural health monitoring of defense and aerospace vehicles in extreme environments. Commercial application: Although developed for use in aerospace applications, the passive conformal RF device technology could be used on a wide variety of industrial testing and structural health monitoring applications.

REFERENCES:

1. Wireless Strain Sensing Networks; S.W. Arms, C.P. Townsend, J.H. Galbreath, A.T. Newhard 2nd European Workshop on Structural Health Monitoring, Munich, Germany, 7-9 July 2004 MicroStrain, Inc., 310 Hurricane Lane, Unit 4, Williston, VT 05495 www.microstrain.com

2. An Experimental and Theoretical Characterization of a Broadband Arbitrarily Polarized Rectenna Array; J. A. Hagerty, Z. Popovic; Department of Electrical and Computer Engineering, University of Colorado Bolder, CO; IEEE, MTT-S Digest 2001 pgs 1855-1858.

3. The RF-Powered Surface Wave Sensor Oscillator—A Successful Alternative to Passive Wireless Sensing; Ivan D. Avramov; ieee transactions on ultrasonics, ferroelectrics, and frequency control, vol. 51, no. 9, September 2004 pg 1148.

4. Wireless Telemetry for Gas-Turbine Applications; Russell G. DeAnna; U.S. Army Research Laboratory, Glenn Research Center, Cleveland, Ohio; NASA/TM—2000-209815 March 2000.

KEYWORDS: strain sensor, wireless sensor, passive sensor, conformal sensor

AF08-BT02 TITLE: Adaptive Integrated Multi-Modal Sensing Array

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design and fabricate adaptive, staring, multi-modal imaging sensor based on co-registered detector elements that utilize novel electronic and photonic materials and structures, resulting in spatial, spectral (ultra-violet (UV) to radio frequency (RF)), and polarimetric detection functionality integrated into a single focal plane array package.

DESCRIPTION: The premise of this research is that developing adaptive multi-modal sensors that can capture multiple electromagnetic observables (intensity, wavelength, polarization, phase, etc..) in a time-resolved, 'staring' imaging format will provide dramatically enhanced detect and ID capability for extremely challenging military problems involving low contrast targets over broad areas in a highly dynamic scene. Battlefield sensing requirements include finding and tracking individuals of interest in populated urban areas, detecting activity and materials indicative of IED placement, and detecting and identifying threatening space objects at long ranges. Historically, military target recognition involved conventional military objects exhibiting unique spatial and spectral signatures that were generally isolated from densely populated areas. However, target recognition problems of today include discriminating a multitude of complex objects deeply embedded in urban areas, day and night, where the most common urban objects can have tactical significance, and achieving high detection probability is critical to mission success. Current-generation remote sensing methods (e.g., broadband FLIR) are limited in their ability to search and detect camouflaged targets in deep-hide or highly-cluttered backgrounds. Proven approaches for enhancing deep-hide, high-clutter target recognition includes utilization of multi- to hyper-spectra exploitation to improve signal-to-clutter ratio, and fusing multi-modal/multi-discriminant data, such as FLIR with SAR, to significantly reduce the amount of processing required for target classification, while simultaneously increasing target ID confidence.

Limitations facing state-of-the-art multi- and hyper-spectral imagers include their 'step-stare' mode of operation (vs. desired starring mode) with revisit times that compromise detection of rapid moving targets, and their fixed-multi/hyper-band construct that can result in a tremendous amount of unimportant data for exploitation. Also, today's airborne hyper-spectral sensors are massive, typically 4-5X that of typical FLIR sensor units employed on tactical aircraft and weapons platforms, and they also require greater sensitivity than typical FLIR sensors to overcome the reduced photon count in narrow wavelength bands. Challenges confronting fusion of multi-discriminant data from single-mode detectors includes handling translational registration errors, and a lack of robust, efficient feature extraction and correlation capabilities. To avoid the problem of unnecessary or unproductive sensor use and computations, it would be desirable to 'intelligently' select 'on-the-fly' an optimum subset of sensors and sensor settings that are most decision-relevant. While this will be very difficult requiring breakthroughs in many sensing technology fronts, emerging innovations in semiconductor materials, device structures, and information sciences offer many interesting opportunities. A 'home-run' approach of interest is to innovate and develop a tunable multi-mode, vertically-integrated (common sensor package), large-format starring focal plane array to accommodate the dynamic sensing requirements dictated by the dynamic target scene. This would involve actively controlling sensor modes and settings to optimize information gathering in a knowledge-based manner with an identifiable selection criterion.

PHASE I: Perform feasibility studies for novel sensor designs through modeling and experimental demonstrations, and calculate potential multi-modal sensor design capabilities and performance parameters. The program focus is on design, modeling and simulation of novel concepts for high-performance tunable multi-modal (UV-RF) focal plane arrays. This includes innovative physical device concepts (i.e., utilizing nanomaterials, nanostructures, hetero-material integration schemes, electrical interconnect schemes, etc.) and prediction of fused-mode detector output signals, in coordination with first-order benefits analysis modeling of expected downstream data exploitation. Novel multi-modal detector designs should be guided by consideration of how they can optimally exploit phenomenology of general multi-mode target scene signatures; how can multi-mode data streams be fused and interpreted in novel and beneficial ways. For example, fused spectral-polarimetric signatures provide information on target material composition, surface characteristics, and 3-D shape simultaneously from a single sensor snapshot, where information in the spectral dependence on polarization state may not be evident from separated polarization and spectral data. To exploit these and other multi-mode opportunities, a coordinated multi-discipline research team experienced in detector device design, and knowledgeable in data fusion and image processing and exploitation will be needed. Sensing modalities of interest include spatial, spectral, polarimetric, radiometric, and temporal; wavelengths of interest span UV (0.2um) to RF (mm). The envisioned multi-modal device design should build from extensive developments in both passive and active sensing, but specifically address the basic research aspect of multi-modal integration into a common sensor package (e.g., detector array).

PHASE II: Demonstrate a working prototype for an adaptive, integrated multi-mode sensing device concept and implementation scheme based on high priority spectrum and mode considerations provided by the government. Perform appropriate sensor design modeling and performance analysis of hardware and software design implementations, and fabricate and characterize full-up prototype devices.

PHASE III / DUAL USE: Military application: Military applications include compact, smart, high-fidelity battlefield sensing for emerging layered sensing concepts. Commercial application: Commercial applications include fabrication of high fidelity multi-functional sensing capabilities enabling for a multitude or emerging photonics applicaions.

REFERENCES:
1. S. Krishna, et al., “Hot dot detectors,” IEEE Circuits and Devices Magazine,” vol. 18, pp.14-24 (January 2002).

2. W. Chen and T. G. Andersson, “Intersubband transitions for differently shaped quantum wells under an applied electric field,” Applied Physics Letters, vol. 60, pp. 1591-1593 (1992).

3. Y. Wei, et al., “Quantum dots of InAs/GaSb type-II superlattice for infrared sensing,” Mat. Res. Soc. Symp. Proc. vol. 692, H3.1.1 (2002).

4. D. Kim, et al., “Imaging multispectral polarimetric sensor: single-pixel design, fabrication, and characterization,” Applied Optics, vol. 42, pp. 3756-3764 (July 2003).

KEYWORDS: multi-spectral, hyperspectral, polarization, infrared detectors, nanotechnology, imager, polarimeter, optical properties, nano-structured materials

AF08-BT03 TITLE: <u>Development of Multidisciplinary, Multi-Fidelity Analysis and Integration of Aerospace Vehicles</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To pioneer innovative methods for representing, managing, and fusing information of various levels of fidelity within an engineering discipline and across multiple disciplines for a wide-range of analysis and design tools.

DESCRIPTION: Computational modeling and simulation techniques are sufficiently advanced for routine use at various stages of the system design process, particularly at the sub-system and component level. The complete analysis of an aerospace system as a whole remains a difficult and on-going challenge. The challenge is compounded with the many technical disciplines involved, each capable of a range of modeling techniques and levels of fidelity to the physics. The earliest attempts at vehicle analysis tools were limited to single disciplines at low levels of physical fidelity. Over the years, models improved as modern computing enabled high-fidelity, physics-based analysis and design tools. Another trend combines models from different disciplines for a multi-disciplinary approach. Some very advanced software provide interface environments where users may select from a range of analysis tool options, e.g., in a framework environment [1, 2].

Current methodologies for the design, analysis, and optimization of air vehicles and vehicle systems and sub-systems rely on a variety of capabilities. Existing capabilities are multi-faceted in terms of design area and specialty (focusing on fluid dynamic, propulsive, aerodynamic, fueling, structural, and thermal systems, etc.). Furthermore, they are multi-level in terms of complexity and degree of sophistication, ranging from simple (but rapid) parametric engineering tools to complex multi-dimensional coupled partial-differential equation solvers. They also include discrete integrated multi-disciplinary system solvers (highly synergistic suites of sub-system and specialty computational design tools) which are becoming increasingly capable in providing complex system-level design, analysis, and optimization. Most computational design capabilities utilized in preliminary design optimization studies are relatively lower-order tools. Such tools allow reasonable computational turn-around times for what is generally a highly iterative process. Further into the design process higher order tools (such as three-dimensional computational fluid dynamics solvers for fluid systems and complex finite element solvers for structural systems) are utilized (most generally on the sub-system level) in order to provide very detailed information relevant to actual sub-system performance and operability. A revolution in vehicle analysis will follow when users can determine with confidence when high, medium, and low fidelity analysis are appropriate and combine the output seamlessly over an exhaustive range of conditions. It has not yet been discovered how to realize this merging and managing of information from multiple analysis tools.

This topic calls for the exploration and innovation of methods for representing and managing information from a wide range of analysis tools, including the mathematical formulation to determine the need for higher fidelity simulations/solutions. One aspect of the research will be the study of appropriate mathematical models for capturing and combining information of varying fidelity. Example methods may include, but are not limited to, model reduction techniques, neural networks, response surfaces, design of experiments, and data fusion methods [3]. Another critical aspect of the research will be developing and assessing procedures for integrating information from different disciplines and accounting for the interaction physics [4]. The mathematical models and procedures developed will allow users to manage uncertainty and to account fully for the relevant physics of air vehicle systems with potential applications to high-speed vehicles.

PHASE I: Define baseline problem on a simplified system or component with at least two interacting disciplines and at least two different levels of fidelity. Develop candidate approaches for representing and integrating information from each discipline and model. Apply to baseline case and assess suitability to represent analysis data.

PHASE II: Define problem with increased geometric and/or multi-disciplinary complexity compared to Phase I. Select the most promising concepts from Phase I and develop procedures for integrating information from several analysis tools. Demonstrate capability to synthesize variable data and interactions from multiple disciplines.

PHASE III / DUAL USE: Military application: High-payoff military applications include improved analysis of multidisciplinary interaction for developing concepts in advanced sensor platforms, future strike, and access-to-space vehicles. Commercial application: Virtually every commercial market that deals with some aspect of system analysis could benefit from this technology. High efficiency commercial aircraft, more efficient aircraft engines, and improved

REFERENCES:
1. Briceño, S.I. and Mavris, D.N., "Implementation of a Physics–Based Decision–Making Framework for Evaluation of the Multidisciplinary Aircraft Uncertainty," SAE World Aviation Congress, 09–12 Sept. 2003.

2. Liu, Weiyu, and Batill, S.M., "Gradient–Enhanced Neural Network Response Surface Approximations," AIAA Paper 2000–4923, Long Beach, CA, September 2000.

3. Stephen J. Leary, Atul Bhaskar, Andy J. Keane, "A Knowledge-Based Approach To Response Surface Modelling in Multifidelity Optimization," Journal of Global Optimization Volume 26, Issue 3 (July 2003) pp. 297–319.

4. Simulation–Based Engineering Science: Revolutionizing Engineering Science through Simulation, Report of the National Science Foundation Blue Ribbon Panel, May 2006. www.nsf.gov/pubs/reports/sbes_final_report.pdf.

KEYWORDS: multi-fidelity analysis/design, multi-disciplinary analysis/design, data fusion, intelligent tools, knowledge/data management

AF08-BT04 TITLE: Full-field, High Temperature Strain and Displacement Measurement

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a full-field data capture capability for the displacement vector(u,v,w)and in-plane strain tensorof a structural component subjected to radiant heat in an acoustic environment.

DESCRIPTION: In order to validate high temperature modeling and simulation predictions of structural components, high-quality, robust experimental techniques which capture the full-field mechanical and thermal response are required. Not only should the implementation exhibit robustness over the temperature range (20 C ¡Ü T ¡Ü 1650 C); the system must also be insensitive to acoustic noise/excitation (¡Ü 170 dB). The total strain field measurement should be accurate to within 200 micro-strain over the range -10,000 ¦Ì¦Å ¡Ü ¦Å ¡Ü 10,000 ¦Ì¦Å while the absolute error in the temperature field should be no greater than 2.5%. If successful, the new experimental capability will provide unprecedented data capture of the heated side of a high temperature component. This data is invaluable for gaining understanding of structural and material response, damage initiation, progressive damage, and ultimately limit state attainment in moderately high temperature material systems.

Full-field techniques such as Digital Image Correlation (DIC) have been successfully used at room and elevated temperature up to the point at which the reflected radiation from the panel saturates the cameras. Other techniques which utilize laser illumination, e.g., Electronic Speckle Pattern Inferferometry (ESPI), have also been employed but still suffer from an inability to determine the location of the local deformation as the part begins to glow. The desired structural component sizes range from a few millimeters up to several meters. Therefore, the developed technique must provide accurate results over several orders of magnitude in field of view.

The full-field technique should consider proper filtering of visible light, proper illumination of the specimen, and adequate data capture rates. It is expected that the effects of natural and forced convection could influence techniques which rely on optical measurement (i.e. refraction). A handling plan which addresses these coupled issues along with a verification and validation approach is considered a necessary part of this effort.

Anticipated deliverables for Phase I effort: A detailed approach that addresses perceived and anticipated difficulties along with a systematic means of addressing these technology hurdles should be part of phase I. In addition, the technological approach should be demonstrated on a small scale. For example, if DIC is used, a single camera capable of surviving the thermal/acoustic environment should demonstrate data capture while the part is glowing. Thermocouples can be used to provide independent validation of the temperature field. Along with material property data, this data can be used to validate the deformation state of the specimen (e.g., thermal strain = CTE*∆T) in an unconstrained configuration.

Anticipated deliverables for Phase II effort: Phase II amounts to a scale up in size along with inclusion of capture of the thermal field. In phase II, multiple cameras will be integrated into a typical ¡°lamp bank¡± setup. The multiple camera system will integrate the views from the different cameras into a single full-field view through software/image manipulation. The effects of light refraction through the visible medium will be quantified and validated. A successful phase II effort will include delivery of a system which successfully captures the full-field displacement, strain and thermal fields of a hot part subjected to acoustic excitation in a lab setting.

PHASE I: Conceptualize and demonstrate the capability to capture the full field displacement and strain of a ¡°glowing¡± specimen where the visible light spectrum is saturated. The specimen should be subjected to a known thermal field for ease in validation.

PHASE II: Develop and construct a prototype system capable of capturing the full-field responses (thermal, displacement, and strain) of a structural component subjected to radiant heat and acoustic noise. Validate performance through rigorous test plan execution and provide associated process capability data.

PHASE III / DUAL USE: Military application: This technology is needed for validation of high-speed (hypersonic) air and spacecraft components and structures. Commercial application: Any application which requires evaluation of elevated temperature components would benefit from this technology.

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KEYWORDS: Full-field response, Digital image correlation, Laser Speckle Interferometry

AF08-BT05 TITLE: Guidestar Enhancement for Adaptive-Optical Systems on Large-Aperture Telescopes

TECHNOLOGY AREAS: Battlespace

OBJECTIVE: Develop and implement a method to enhance the local atomic sodium density in the mesosphere using ground-based sources.

DESCRIPTION: A global layer of sodium (Na) atoms exists in the mesosphere between 80 and 100 km (von Zahn et. al. 1987) with a peak density occurring between 90 and 95 km. The Sodium Guidestar Adaptive Optics System (NGAS) program for the 3.5-meter telescope at the Starfire Optical Range (SOR), Kirtland AFB, NM uses light emitted from a mesospheric sodium guidestar to perform adaptive-optical correction on distortion from atmospheric turbulence. Adaptive Optics (AO) allows much improved imaging of satellites which improves the Air Force Space Situation Awareness (SSA) program. The image quality is dependant on guidestar brightness which in turn depends on the Na density. The density of sodium atoms in the lower atmosphere varies by a factor 4 annually (Drummond et. al. 2007). This variation in guidestar radiance reduces the sky coverage and the number of months a year the AO system may be used. The objective is to stabilize and enhance the Na radiance. Models of the chemistry and physics of mesospheric atomic sodium have been developed. These models identify chemical and physical reservoirs which could release Na atoms (von Zahn et al. 1987, Plane et. al. 1999, McNeil et al. 1995, Cox et al. 2001). The goals of this topic are to identify potential atomic Na reservoirs in the mesosphere, develop a comprehensive and feasible method to release Na from these reservoirs using ground-based sources, and estimate the amount of Na that could be released, how long it would take to exact the release and how long the enhanced density would persist. The purposed method may use SOR facilities such as, the sodium guidestar pump fasor to excite atomic Na, the 3.5-meter telescope to observe guidestar radiance, and the beam director to launch a beam that might be used to release atomic Na.

PHASE I: Identify potential atomic Na reservoirs in the mesosphere. Develop a comprehensive and feasible method to release Na from these reservoirs using ground-based sources.

PHASE II: Develop and implement an experiment to test the method described in Phase I. Observe the increase in the local Na density in the mesosphere and measure it. Make sure Na density enhancement is not due to natural fluctuations based on location, the earth's magnetic field, sudden sodium layers, aurora etc. Report the results.

PHASE III / DUAL USE: Military application: Sodium guidestars are used by AFRL to improve imaging of satellites and enhance the Air Force Space Situation Awareness (SSA) program. Commercial application: A brighter Na guidestar could benefit Keck Observatory, Gemini Observatories, European Southern Observatory, Subaru Telescope, Steward Observatories, Kitt-Peak Observatory, Thirty-meter telescope...

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KEYWORDS: ground-based optical telescopes,atmospheric correction,adaptive optics,artificial beacon, mesospheric sodium guidestar,mesospheric sodium chemistry,laser-pumped guidestar,natural guidestar

AF08-BT06 TITLE: Cyber Superiority for Air Force Combatant Commanders

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The United States Air Force is looking for technological innovations to provide operators with robust situational awareness, control of electro-magnetic spectrum, and maneuverability in cyberspace.

DESCRIPTION: Military dependence on information-based technology, completely networked systems, telecommunications, and other technologies that use electronics and the electro-magnetic spectrum have led to the recognition of cyberspace as a domain. Our adversaries are actively seeking ways to exploit our reliance on the cyberspace domain to further their own interests. We must do what we can to secure our national info-structure, prevent cyber attacks, and maintain our freedom to operate in the cyberspace domain. The cyber domain is where combatant commanders join all of the Services' warfighting capabilities to conduct interdependent operations. Sensor operations in all domains are integrated in the cyberspace to allow information to be gathered quickly and data exchanged more precisely. New cyberspace capabilities are needed to enhance data integration, provide situational awareness, and provide air, space, and cyber operations integration, so the commander can control forces and the combat environment.

PHASE I: Perform preliminary investigations of advanced cyberspace capabilities that can integrate global and theater capabilities in support of the combatant commander.

PHASE II: Perform a proof-of-concept demonstration of advanced cyberspace capabilities.

PHASE III / DUAL USE: Military application: Results of the research will have application to computer networks, airfield operations, and telecommunication systems. Commercial application: Results of the research will have application to commercial computer networks, airline operations, and telecommunication systems.

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KEYWORDS: electro-magnetic spectrum control, situational awareness, battle management, sensor resource management, cyberspace

AF08-BT07 TITLE: Hybrid Structures for Improved Damage Tolerance of Unitized Structures

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop innovative structural concepts of tailored, graded or hybrid materials that enhance the damage tolerance capability of unitized structures.

DESCRIPTION: Conventional aircraft construction techniques inherently include features that are damage tolerant. Unitized structure tends to lack these features. In this effort typical unitized structural concepts shall be evaluated and fatigue or damage critical locations identified. For these locations, metallic and/or composite structural concepts of tailored, graded or hybrid materials shall be developed that enhance the damage tolerance capability of unitized structures.

PHASE I: Develop analytical tools and structural concepts of tailored or hybrid materials that enhance the damage tolerance capability of unitized structures. Candidate approaches will be conceptualized, demonstrated and subjected to realistic vehicle flight loadings to assess damage tolerance capability

PHASE II: Select the concept that has the most damage tolerance structure capability. Design a structural component, and manufacture and test the article to verify the concept.

PHASE III / DUAL USE: Military application: The structural technology developed will be applicable to large transport aircraft and other military vehicles. Commercial application: Commercial airliners and military transports have similar loading requirements, and thus the technology generated will be applicable to the each class.

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C. A. J. R. VERMEEREN, Faculty of Aerospace Engineering, Delft University of Technology, Kluyverweg 1, 2629 HS Delft.

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KEYWORDS: Damage tolerance, unitized structures, hybrid structures, tailored properties, metallic structures, composite structures

AF08-BT08 TITLE: Silicon-Based Nanomembrane Photonic and Electronic Components

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Design and develop silicon-based adaptive intelligent photonic/electronic components and systems for enhanced-performance imaging, communication, and information processing, using silicon-based nanomembranes, a potentially disruptive platform technology.

DESCRIPTION: Rigid, flat, crystallographically nearly perfect Si has been the mainstay of microelectronics, the leading technology during the last four decades. Significant improvements in this technology are possible, in particular in monolithic integration of optics into Si-based microelectronics and all-optic Si-based integrated microphotonics or nanophotonics. A potentially disruptive new platform technology, crystalline Si-based nanomembranes, not only suggests new and simpler paths to achieve these goals but extends the reach of Si into areas of adaptive intelligent photonics and electronics not thought possible only a short while ago.

Si nanomembranes are single crystals of Si (or equally Ge or layered combinations) that have been released from SOI (or GOI, Si, Ge etc.) and re-deposited on new substrates. They offer key technical advantages:
1) They provide a method for transferring single-crystal Si (or Ge) to any other substrate, including flexible hosts. Thus integration of best features of different materials is feasible.
2) They are stackable. Multiple transfers will produce membrane heterostructures.
3) They are flexible, deformable, and conformable, and can be manipulated dynamically.
4) They can be composed of heterolayers of Si, SiGe, SiGeC, etc. Such structures share strain coherently between all layers, resulting, e.g., in strained Si with zero dislocations and offering the prospect of engineering the Si (or Ge, etc.) band structure.
5) They can be lithographically patterned into any shape, including nanowires.
7) SiNMs are processable like bulk Si and retain the electronic properties of bulk Si. Thus all manner of Si devices can be fabricated, and high-volume manufacturing is feasible.

Of interest are innovative approaches for the development of 1) flexible intelligent photonics (FIP): adaptive frequency selective photonics components, modulators, mechano-activated adaptive optics, 3D photonic crystals and membrane waveguides; 2) strain engineered ultrasensitive, high-speed SiNM/GeNM photodetectors; 3) Si-membrane-based light sources; 4) high-speed flexible, conformal, and/or 3-D elec-tronics; 5) hybrid-orientation technology (HOT): fast flexible CMOS with integration on other hosts; 6) flexible conformal photovoltaics - integrated personal portable power sources; or 7) Si-membrane based thermoelectric materials. Adaptive intelligent photonic/electronic systems, improved detectors and imagers, light sources, conformal electronics and power sources, and very fast flexible electronics would all be of great value to the DoD, significantly advancing DoD capabilities, with potential impacts in the areas of energy-efficient ultra-compact dynamic intelligent information collection, high-capacity data networks, and adaptive rapid-response systems. Con-sequent commercial applications are legion.

PHASE I: Demonstrate through successful fabrication of a feasibility design innovative approaches for one or more of the above listed technologies. Feasibility of a novel application of Si nanomembranes (e.g., a 3D photonic crystal device, an advanced photodetector, a flexible-PV personal power source on textiles, or membrane based adaptive optics) will involve simulation of the device design, predicted specifications of the design, and demonstration of the feasibility of processing steps.

PHASE II: Develop a manufacturable prototype of a device in one or more of the above technology areas. Demonstrate integration with requisite control and necessary other components to make a complete photonic/electronic/power system. Demonstrate superiority over Si wafer-based devices, where the device is an improvement over current technology rather than new technology.

PHASE III / DUAL USE: Military application: Si nanomembranes have the potential for revolutionizing many fields, including imaging, communication, information processing, sensing, energy conversion, and even personalized medicine. Commercial application: Membrane-based light sources can provide inexpensive optical inter-connects and optical add/drop multiplexers for direct optical connections without the need of optical-to-electrical conversion.

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KEYWORDS: silicon nanomembranes, adaptive optics,CMOS imagers, photodetectors, lasers,silicon microphotonics,strain engineering,photonic crystals,light emitting diodes, LED, switches,waveguides,thermoelectrics, photovoltaics,HOT,fast flexible electronics, nanostructures,nanophotonics,silicon on insulator, membrane bonding,conformal electronics.

AF08-BT09 TITLE: Variable Thrust / Specific Impulse Electrospray Propulsion

TECHNOLOGY AREAS: Space Platforms

OBJECTIVE: Investigate means to operate a single-thruster / single propellant electrospray propulsion within a wide specific impulse / thrust range while maximizing the performance.

DESCRIPTION: The goal of this research is to identify propellants for electrospray propulsion able to cover at high propulsion efficiency an unusually wide range of specific impulses (Isp) going from several hundred seconds, typical of colloidal propulsion (emission of just drops, with no ions), up to values of thousands of seconds, typical of purely ionic propulsion (emission of just ions with no drops). Available mixtures have already shown an ability to span efficiently a wide Isp range, up to a few hundred seconds. Therefore, ions will only coexist with unconventionally small drops, both having comparable ejection speeds, with associated favorable propulsion efficiency [Ref 1]. However, the electrical conductivity of these mixtures was insufficient to achieve the desired high specific impulse. Several studies have already demonstrated the ability of ionic liquids to emit pure ion beams to achieve very high specific impulses at high propulsion efficiency. Ionic liquids can also emit drop and ion mixtures that achieve smaller and controllable specific impulses, but so far this has always happened under relatively low propulsive efficiency. The reason for this inefficiency is that the drops produced from ionic liquids in this mixed regime have been relatively large. In several recent articles [Ref 2] authors have noted that some ionic liquids of high conductivity and surface tension produce emissions of relatively small clusters which may give a controllable specific range at high propulsive efficiencies.

PHASE I: To identify propellant mixtures that provide emissions with small cluster formations, which permit a specific impulse control at acceptable efficiency. Challenge is to design propellants & propulsion schemes able to cover both high & low specific impulse range with a fixed thruster and propellant.

PHASE II: Based on the advances in Phase I, build an electrospray thruster that using optimized propellant mixture that can provide controllable specific range at high propulsive efficiencies.

PHASE III / DUAL USE: Military application: Military application: Electrospray propulsion with variable specific impulse and thrust is well-suited for on-board spacecraft propulsion that needs to perform multiple operations.

Commercial application: Variable specific impulse electrospray propulsion is a multi functional thruster that can be used orbit raising, drag correction, and maneuvering of the commercial satellites.

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KEYWORDS: electrospray thrusters, electric propulsion, ionic propellants

AF08-BT10 TITLE: <u>Graphene Fabrication Process and Apparatus Development</u>

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Synthesis of uniform mono-layer, defect free epitaxial graphene films with u>10E4 for electronic device development for two-dimensional thin film.

DESCRIPTION: Graphene has unique properties: half-integer quantum Hall effect, quantized electrical resistivity, zero band-gap with zero density of states at the Fermi-level. To develop and exploit these and other electronic properties, new techniques and fabrication apparatus for reproducible growth of high structural quality graphene layers are needed on semiconductor and dielectric substrates of at least 5 cm in diameter.

PHASE I: Vendor to determine most auspicious fabrication technique for large area, uniform high-quality graphene sheets by thermal reduction of SiC, MBE, evaporation, CVD, HPCVD, beam assisted CVD, or pyrolysis. Vendor will demonstrate efficacy by Raman spectroscopy, and provide samples to AFRL/RX.

PHASE II: With academic partner(s) and sample evaluation at AFRL/RX, confirm graphene technique based on electronic/photonic evaluations, and on equipment requirements. Additional experiments to be performed with construction of a prototype production system capable of at least 5 cm diameter single crystal films. Alpha testing to be performed at vendor’s site, and system beta testing at AFRL.

PHASE III / DUAL USE: Military application: Graphene has great potential electronic/photonic applications for terahertz sensors, signal sources, and a wide variety of nano-scale detectors and high power handling devices essential to the USAF. Commercial application: Graphene R&D is hampered by lack of large area, quality films on suitable substrates. Having machinery producing high quality graphene films will lead to dynamic applications of this technology.

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KEYWORDS: Graphene, Terahertz, THz, Sensors, Thin-films

AF08-BT11 TITLE: Thermally Remendable Composite Structures with Resistive Heating Network of Carbon Fibers

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: To demonstrate the use of electrically conducting reinforcement of carbon fibers as a network for damage detection as well as resistive heating for thermally remendable composite structures.

DESCRIPTION: Carbon fiber reinforced polymer composites, commonly used in aerospace structural applications, are vulnerable to foreign object impact, and incipient damages created by impact loading are not easily detectable because of their sub-surface nature. Extensive research efforts were performed to assess the extent and location of damage by incorporating embedded sensors or sensory materials into the structures. Most notable among them are on-going efforts to utilize electrically conductive nature of built-in reinforcements of carbon fibers in detecting physical damages of composites, such as fiber breakage, matrix/interface cracking and delamination, based on the increase of electrical resistance [1,2]. One interesting fact is that the same phenomenon of increased electrical resistance of damaged composites leads to local heating over the damage area. In addition to this local resistive heating effect, conducting path of carbon fibers can distribute internally or externally applied heat through the composites. As result, when thermally remendable crosslinked polymers [3-5] are used as composite matrices, carbon fibers can serve as self-heating network to induce in-situ repair or healing of matrix/interface cracks and delamination.

PHASE I: Demonstrate the concept of using carbon fibers as heating elements to induce in-situ repair of microcracks and delamination for fiber composites with thermally remendable polymers as matrices. Investigate the most effective methods of applying the electric current uniformly.

PHASE II: Quantify the in-situ repair or healing performance under static and fatigue loading utilizing scaled-up composite configurations. Identify the systems of thermally remendable polymers that are environmentally stable. Develop autonomous damage detection software system that directly relates changes in electrical resistance to damage state.

PHASE III / DUAL USE: Military application: Utilization of in-situ repair ability of materials to enhance the service life of structural composites in large scale will offer tremendous potential of life cycle cost saving. Commercial application: Self-diagnosis capability will grant early warning of the damage evolution in composite structures, thereby allowing greater survivability of space, air, sea and land vehicles made of composites.

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KEYWORDS: Thermally remendable polymers, Carbon fiber composites, Damage repair and healing, Health monitoring, Electrical resistivity

AF08-BT12 TITLE: Development of Compact, Lightweight Power Transmission Devices for Directed Energy Applications

TECHNOLOGY AREAS: Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: To design and test new compact and lightweight power transmission devices based on recently developed higher power/weight wire conductors. Maximize power/weight ratios and minimize system heat losses including refrigeration of applicable devices.

DESCRIPTION: The development of new wire conductors in the past 20 years with 5x to 200x higher current/weight capacity than Cu introduces the potential to improve the performance and efficiency of electric current transmission systems for high power and directed energy applications. New materials with higher conductivity developed include doped carbon graphite or nanotubes, hyperconducting metal alloys, or novel or high temperature superconductors operating at 20K to 80K. The development of improved power/weight directed energy (DE) devices is on-going,(1) however the problems of electrical power transmission to-and-from these devices is not being considered presently. For example, the weight of power cables running from optimized airborne high power generators are likely to weigh more than the generator itself, and heat losses which are proportional to the increased device power levels can affect system performance. To further improve DE device operation at 50K to 300K, the design and optimization of power transmission devices is necessary to reduce system heat loss and weight. While there is presently on-going work on development of necessary components for high voltage power systems for commercial power industries,(2,3) there is relatively little effort optimizing power transmission systems for low voltage operation and low AC frequency or DC systems which are typical for many aircraft and directed energy devices. Previously development of 100-1500 MW superconducting power lines for high voltage operation (20-120 kv) have demonstrated 4-40x reduction of total system heat loss including cryogenics and approximate 10x reduction of size and weight for the transmission cables, for commercially viable systems.(2) For any DE application, the development of refrigerated (or cryogenic) power transmission systems can be considered if the system size, weight and power losses including refrigeration can be lower than comparable room-temperature Cu and solid-state components.

This proposal focuses on design and optimization of high power transmission devices including lines, current leads, bus bars, switches or other, primarily for low voltage including DC and low AC frequency systems. The development of systems operating at 50K to 300 K are of first interest, however devices operating at < 50K can be considered if they demonstrate competitive system size, weight and/or power loss reduction. For directed energy (DE) devices such as > MW gyrotrons and generators that utilize YBCO high-temperature-superconductor (HTS) wires and cryogenic refrigeration, operation temperatures from 50 K to 80K are needed.(1)

PHASE I: Phase I of the proposal should address the following criteria:
i) Design and optimization of devices for specific parameter ranges: currents from 1000A to 30000A, operation temperatures from 50K to 80K for HTS YBCO conductors, DC and AC voltages from 0 to 300 Volts, and DC-AC operation frequencies of 0 hz to 1 khz. The design of HTS current leads including possible choices of dielectric insulation are understood, however must be optimized for different operation parameters.3
ii) Optimized design of devices to maximize power/weight ratios, and minimize system heat loss particularly for aircraft applications.
iii) Increase duty cycles for both pulsed and long duration operation.

iv) System lifetime reliability is an issue in the design and consideration of cryogenic parts including vacuum lines. Where possible, established technologies should be utilized when appropriate. However if limitations of established technologies can be documented, new proposals can be considered.

PHASE II: Phase II will build and test the devices from Phase I. If possible, redesign and reoptimization of the devices may be done using lessons learned.

PHASE III / DUAL USE: Military application: Directed energy weapons, high power gyrotrons, high energy lasers. Commercial application: Lower weight and compact high power transmission wires in commercial aircraft. Reduction of weight would result in direct benefit to the commercial airline industry. Other applications include power transmission devices for the next generation of power industry or science applications utilizing high temperature superconductor or other novel conductor wires. Examples of next generation power devices include > 30 Tesla class $YBaCu_2O_{7-x}$ (YBCO) high temperature superconducting magnets or detectors needed for > TeV particle physics accelerators, or YBCO-based NMR medical magnets operating at 77K. These are multimillion or billion dollar industries that can be impacted by new technologies.

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KEYWORDS: directed energy, power transmission, heat loss, cryogenics, advanced wire conductors, high temperature superconductors, superconductors, current leads, low voltage, AC, DC, aircraft

AF08-BT13 TITLE: Heat Transfer Prediction in Transitional Hypersonic Flow

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop a computational tool capable of accurately predicting wall heat transfer rates in hypersonic boundary layers undergoing transition from laminar to turbulent flow.

DESCRIPTION: Extreme heat transfer rates are arguably the prime constraint in the design of hypersonic aircraft. Some success has been obtained in predicting heating rates in fully laminar or fully turbulent flow, but accurate predictions in a transitional regime remain elusive. Uncertainty in heat transfer rate requires large factors of safety to be used in current vehicle designs. Improved computational accuracy could lead to significant improvements in hypersonic vehicle performance by allowing the removal of unnecessary weight in the thermal protection system. The purpose of this effort is to develop a robust, accurate computational tool for predicting wall heat transfer rates in transitional hypersonic boundary layers. Prediction of the heat transfer overshoot at transition is of particular interest. Innovative solutions based on either direct numerical simulation or reduced order modeling are encouraged.

PHASE I: Develop prototype computer code for heat transfer prediction, and carry out demonstration calculations. Validate computational tool against benchmark experimental datasets obtained from the archival literature. Begin efforts for developing a product usable by a non-specialist, and formulate plan for Phase II development.

PHASE II: Continue development of prototype computer code, emphasizing code robustness and user-friendliness. Continue code verification and validation. Demonstrate code performance on realistic hypersonic vehicle configurations.

PHASE III / DUAL USE: Military application: Accurate predication of transitional heat transfer on hypersonic systems will enable future military applications including Long-Range and Prompt Global Strike Options and Responsive Space Access. Commercial application: Potential dual-use applications include commercial space access, supersonic civilian transport, and aircraft engine design.

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KEYWORDS: Hypersonic, Laminar-turbulent transition, Heat transfer, Computation, Numerical

AF08-BT14 TITLE: NON-THERMIONIC CATHODE FOR HIGH POWER, LONG PULSE, LONG LIFETIME MAGNETRONS

TECHNOLOGY AREAS: Materials/Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), which controls the export and import of defense-related material and services. Offerors must disclose any proposed use of foreign nationals, their country of origin, and what tasks each would accomplish in the statement of work in accordance with section 3.5.b.(7) of the solicitation.

OBJECTIVE: Develop compact electron emitting cathode capable of replacing the conventional thermionic source without changing the microwave source operation and eliminating the heater for the thermionic cathode.

DESCRIPTION: Numerous Air Force applications require operation of microwave tubes such as the Magnetron at power levels in excess of those currently available in industry. A critical technology in achieving this goal is the development of an electron source capable of generating large area, high current beams approaching space charged limited operation. Conventional technology utilizes thermionic emission as the primary electron source so that increased currents are possible only with increased emitter temperature. Not only does this require additional power but also additional cooling and subsequent reduction in cathode lifetime. In addition, the required 10x increase in current is not practical from conventional heated electron sources. Rather than extend conventional solutions, this topic is designed to investigate non-thermal electron emission solutions which can be scaled to the required current densities (1-10 a/cm^2) and total emission areas (10-100 cm^2). Theses currents must be achieved without excessive gas evolution and should be applicable to ultra-high vacuum techniques such as bake-out and sealed tube operation. An additional critical capability is control of the emission from near zero to the maximum current. This control must be achieved with practical techniques applicable to operation of the high power microwave tube. The program should address basic characteristics of the electron source including electron energy spread, emission uniformity, steady state and time dependent behavior, cathode lifetime and aging characteristics. Techniques of fabrication and operation will be addressed. Finally, a practical embodiment of this cathode will be fabricated and tested in high power microwave tubes of interest to the Air Force.

PHASE I: Based on the physics of electron emission select candidate materials and designs to provide the proper operation of the magnetron. Perform scaled experiments to demonstrate the basic validity of the materials and designs to demonstrate standard operation of the magnetron.

PHASE II: Develop, fabricate and demonstrate a prototype full scale cathode module which produces controlled current from 0 to at least 10 amperes with pulse widths of greater than 10 milliseconds and lifetime suitable for continuous operation in selected high power microwave tubes. Develop a business and commercialization plan for the Phase II engineering development and marketing program.

PHASE III / DUAL USE: Military application: The cathode emitters may be used in switches for electric powered systems requiring long lifetime and high-average power such as all-electric vehicles. Commercial application: The technology developed for electron emitters in vacuum diodes may also be used in pulsed power systems as closing switch electrodes for long lifetime, high average power systems.

REFERENCES:
1. "Development of a 300 kW CW L-band Industrial Heating Magnetron", A.P. Wynn, et al, presented at the 5th IEEE International Vacuum Electronics Conference, April 2004

2. "Twenty-kilowatt 890 Mc/s continuous-wave magnetron" J.R.G. Twisleton, Proc. IEE Vol. 111, No 1, January 1964, ppgs 51-56

3. "Microwave emission from pulsed, relativistic e-beam diodes II. The multiresonator magnetron", A. Palevsky and G. Bekefi, Phys Fluids 22(5), May 1979, ppgs 986-996.

KEYWORDS: cathode, electron, emission

AF08-BT15 TITLE: <u>Combustion Screech Reduction Technologies in Afterburners</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop innovative, low bandwidth, technologies for the control of combustion instabilities for thrust augmentors in high performance gas turbine engines.

DESCRIPTION: Combustion in the gas turbine engine augmentor is governed by many unsteady physical processes. These unsteady processes can result in combustion dynamic instabilities such as screech. Screech modes typically occur in the range of frequencies from hundreds to thousands of Hertz. Screech is due to the complex physical coupling of the wave propagation in the combustion chamber with fluctuations in the heat release of the combustion process. Coupling can produce large pressure fluctuations that can be severe enough to damage engine hardware.

Historically, screech has been mitigated by two very different and highly empirical approaches; damping and active control. Both active control and damping target specific physical processes for the control of instabilities. In the case of damping, liners and resonators have been fashioned to absorb acoustic energy. Acoustic, or screech liners are designed to effect modes whose frequencies are greater than 1 KHz. Liners have proven to be a cost effective and light weight way to control screech modes above 1 KHz. Resonators on the other hand are usually tuned to attack lower frequency modes, less than 1 KHz. To absorb acoustic energy at these frequencies the resonators are physically large. Resonators provide excellent suppression of combustion instability in ground based gas turbine systems, where weight is not significant factor. In aero systems, current resonator technology has a significant system weight penalty and a significant production and sustainment cost penalty.

In the case of “high bandwidth” active control, fuel is modulated at the frequency of the instability using an actuator valve. The phase of the modulation is varied actively until sufficient fuel modulation is out of phase with the instability. This results in suppression of the instability. “High bandwidth” active control has also provided excellent control of combustion instability in ground based gas turbine systems, where weight and actuator power consumption are not significant factor. To date development of an actuator valve with sufficient driving capability that is flight weight and consumes <100 Watts of power is still an open research area.

This research topic will involve the investigation of “low bandwidth” control of unsteady heat release to mitigate combustion instability. Two specific results are desired from this research. The first desired result is an improved understanding of the mechanisms that control unsteady heat release in the augmentor and an improved understanding of how the mechanisms act to couple/decouple the unsteady heat release with the modes of the chamber. The second desired result is the demonstration of innovative “low bandwidth” combustion control technologies. Technology concepts should be developed directly from the improved understanding derived from the research. New technologies should be developed such that they could be easily implemented in current and future gas turbine augmentors with little weight or cost consequence.

Close collaboration with an Original Equipment Manufacturer (OEM) of high performance afterburners is highly encouraged to ensure successful transition of technology concepts at the end of Phase II.

PHASE I: Identify mechanisms that contribute to unsteady heat release. Detail approaches to systematically derive physical understanding of the coupling between unsteady heat release and modes in augmentors. Demonstrate the ability to conduct research and technology demonstration in combustion environment.

PHASE II: Develop the understanding of unsteady heat release and coupling mechanisms associated with screech. Develop innovative technology concepts for the control of combustion instability and demonstrate screech mitigation technologies. Deliverables include research reports and technology concepts and assessment of their ability to control combustion instability.

PHASE III / DUAL USE: Military application: Light weight, and low cost technologies transitioned to military gas turbine OEMs for incorporation into existing and future augmentor design systems. Commercial application: Improved, light weight and low cost technologies have many applications in commercial gas turbine, land based gas turbine power generation, and boiler power generation applications.

REFERENCES:
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KEYWORDS: Augmentor, Combustion, Static Stability, Dynamic Stability, Stability Modeling

AF08-BT16 TITLE: <u>Mid-Infrared Precision Frequency Combs</u>

TECHNOLOGY AREAS: Sensors

OBJECTIVE: The objective of this research is to investigate and develop precision laser frequency combs in the mid-infrared and longer wavelengths.

DESCRIPTION: Precision frequency combs generated by mode-locked bulk crystal and fber solid state lasers have led to revolutionary advances in spectroscopy. The frequency combs, locked to ultra-stable microwave sources, have allowed new levels of measurement in the near-infrared wavelength region through use of Ti:sapphire and Er:fiber gain media. It would be desirable to generate combs at longer wavelengths, to permit precision spectral measurements in the wavelength region of strong molecular absorption bands. Such measurements could impact, for example, calculations of atmospheric transmission, which depend of precise knowledege of molecular energy levels. Laser materials such as Cr:ZnSe and Fe:ZnSe, based on divalent transition metals in a tetrahedral field, have similarities to Ti:sapphire but operate in the mid-IR wavelength region from 2-5 microns. It would be desirable to develop improved, femtosecond-pulse-duration, mode-locked lasers based on these materials or on nonlinear optical techniques, and apply the same techniques of carrier phase control used with Ti:sapphire that have allowed generation of the precision frequency combs. The use of nonlinearities in IR-transmitting fibers could allow extension of the combs into even longer IR wavelengths.

PHASE I: Study laser and nonlinear optical techniques that can lead to the desirable precision frequency combs in the mid-infrared and longer wavelengths. Demonstrate key concepts. Emphasized reduced cost compared to Ti:sapphire systems.

PHASE II: Demonstrate both the short-pulse systems in the mid-infrared or longer wavelength, and demonstrate carrier phase control for precision spectroscopy and metrology. Study and develop prototype systems based on phase I research and phase II efforts, and guided by technical and cost constraints for marketability

PHASE III / DUAL USE: Military application: Compact, inexpensive mid-infrared precision frequency combs would have important applications for gas spectroscopy and sensing, for atmospheric modeling, and for chemical or explosives monitoring. Commercial application: Commercial applications would include the military ones, as well as process control and breath analysis for health monitoring and disease diagnostics.

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1. S. B. Mirov, V. V. Fedorov, I. S. Moskalev, and D. V. Martyshkin, Recent Progress in Transition-Metal-Doped II–VI Mid-IR Lasers, (2007).

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KEYWORDS: Mid-infrared, mode-locked laser, frequency comb, phase-locked carrier

AF08-BT17 TITLE: <u>Development of Diagnostic Model for Hydrogen Permeation through High-Strength Alloys</u>

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The objective is to develop a mathematical model for evaluation of hydrogen permeation through high-strength alloys under corroding conditions.

DESCRIPTION: The practical use of ultrahigh-strength alloys in Air Force environment is limited by cracking hazards due to hydrogen penetration and hydrogen accumulation in the bulk of the alloy. Hydrogen evolution and hydrogen permeation are usually encountered during electrochemical processes such as electroplating, corrosion and cathodic protection. In weakening alloys, hydrogen tends to accumulate in areas if high stress and can reach critical concentration causing microcracks to occur, which can lead to catastrophic fracture that damages the structure. Significant efforts are underway to develop effective barrier coatings which will impede hydrogen absorption, hydrogen permeating an hydrogen embrittlement such as: Zn, Zn-SiO2 composite coatings, Ni or Sn coatings or Zn-Ni, Zn-Sn alloys and Zn-Ni-SiO2 composites. Devanathan-Stachurski permeation technique has been routinely used to investigate the rate of hydrogen permeation through barrier film-coated alloys. However, this technique is unable to provide useful information with regard to hydrogen permeation characteristics and quantitatively to estimate the rate constants of hydrogen discharge, recombination and adsorption reactions. A user friendly model should be developed capable for evaluation of hydrogen entry efficiency and to serve as a diagnostic criteria for determining the effectiveness of various metals and alloys as hydrogen permeation inhibitors.

In the proposed investigation, a mathematical model will be developed which will have capability to provide a quantitative criterion for hydrogen permeation inhibiting efficiency of barrier film-coated alloys. The model will be formulated for hydrogen permeation which proceeds via coupled discharge-chemical recombination reactions under different environmental corroding conditions. From the experimental data of hydrogen evolution and permeation current densities, the model will determine the rate constants of the hydrogen discharge, recombination and adsorption reactions. These kinetic parameters will be used as a basis for comparing the hydrogen entry efficiency of different alloys under various environmental corroding conditions.

The final model will be accessible through a user-friendly interface that will enable Air Force engineers to apply the model for specific aerospace-use conditions. Engineers will be able to estimate the reliability and service life of bare and barrier film-coated high-strength alloys used for aircraft structures. Additionally, they will be able to use a user-friendly software during the initial design process and to engineer structures that are more resistant to hydrogen embrittlement cracking.

PHASE I: A mathematical model will be developed which is capable of evaluating the kinetic constants for different metals and alloys under corroding conditions and to provide a quantitative criterion for their hydrogen permeation inhibiting efficiency.

PHASE II: Develop a user-friendly software to be interfaced with experimental permeation equipments. It will enable Air Force engineers to easily utilize the model, to evaluate hydrogen permeation characteristics, to predict hydrogen embrittlement failure under specific aerospace-use conditions and to engineer structures that are resistant to hydrogen embrittlement cracking.

PHASE III / DUAL USE: Military application: Air Force engineers will be able to estimate the reliability and service life of high-strength alloys for aircraft structures. Commercial application: The model can be used to quantify the hydrogen entry efficiency in processes utilized in metallurgical and metal finishing industries.

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KEYWORDS: High-strength alloy, Barrier coating, Hydrogen embrittlement, Hydrogen permeation, Corrosion, User friendly mathematical model

AF08-BT18 TITLE: Ultradense Plasmonic Integrated Devices and Circuits

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop ultradense, low-power plasmonic integration components and devices for future battlefield sensors and systems.

DESCRIPTION: The use of surface plasmons in guiding metallic structures is one of the most promising approaches for overcoming the diffraction limit of light and significantly increasing levels of integration and miniaturization of integrated optical devices and components. The unique properties of plasmonic waveguides (such as very high mode confinement, ultrasharp bends, etc) promises the level of integration optical components, previously unachievable with any other technology. However, significant advancements in both the design and fabrication of both passive and electro-optically active plasmonic structures are required to transition this technology to practical applications. For example, due to very high dimensional tolerances of plasmonic devices electron-beam lithography is typically used for patterning of plasmonic waveguides, which is slow and expensive process, incompatible with large scale production and low costs, required by military and commercial applications. On the other hand, significant advances in nanofabrication techniques made over the last decade may provide the means to solve this problem. For these reasons, advancements in both theoretical understanding of plasmonic integrated circuits and fabrication techniques are required.

Future battlefield systems will exploit highly sophisticated optical communication and signal processing systems with very high component integration density, low power consumption, fast and low-cost data transfer rates. Successful completion of this program will lead to the development of high quality, robust, photonic circuits that will serve as an integrating medium for optical components and networks and that will perform basic, on-chip functions (such as signal conditioning and signal processing).

PHASE I: Demonstrate feasibility of the ultradense plasmonic components and circuits by modeling. Design an active integrated photonic structure and select the materials and fabrication methods. Demonstrate the validity of key processes. Identify the application, develop a documented set of performance parameters and suggest a viable transition to manufacturing strategy.

PHASE II: Build upon Phase I work and fabricate functional passive plasmonic devices. Design and fabricate and demonstrate the functionality of active plasmonic devices. Address the integration of the developed plasmonic circuits into existing or future communication systems. Demonstrate the scalability of the fabrication process to the large-scale low-cost production in Phase III.

PHASE III / DUAL USE: Military application: Applications of the ultradense integrated photonic components in sensors, signal processing and communications. Commercial application: Enable fabrication and design of optical ultradense functional optoelectronic (OE) circuits for optical communications and optical signal processing.

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1. T. Nikolajsen and K. Leosson, S. I. Bozhevolnyi, “Surface plasmonic polariton based modulators and switches operating at telecom wavelengths,” Appl. Phys. Lett., 85, 5833-5835 (2004).

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KEYWORDS: signal processing, optical components, optical subcomponents, photonic integration, optical processors, nanotechnology, plasmonics, nanofabrication.

AF08-BT19 TITLE: Computational Prediction of Kinetic Rate Constants for Condensed Phases

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: A seamless, efficient computer code to predict reaction rate constants for gas-surface interfaces condensed phase molecules from electronic structure or direct dynamics with predicted error.

DESCRIPTION: Several computer codes, some of them available commercially and others in the public domain, currently exist which can predict the electronic structure of molecules of interest in the condensed phase. Similarly, several codes exist which can predict the kinetics and/or dynamics of a system given the electronic structure of the molecules involved. Several interfaces between some of these codes currently exist, however, none are seamless. They do not predict the likely error based on the level of quantum theory. To make the code useful to kinetic modelers and materials designers it will be necessary to know the certainty of the codes predictions. Further, the current codes are computationally intensive due to the number of necessary data points to make a reasonable prediction of the kinetics. These factors severely hamper or eliminate their usefulness as tools for kinetic modelers and as design tools synthetic chemists and chemical engineers. A code is sought which is seamless, easy to use, computationally efficient and will predictively calculate the rate constants for reactions at gas-surface interfaces and of condensed phase molecules of interest from the results of electronic structure or direct dynamics calculations. The code shall also predict the potential error based on the level of quantum theory used. The code may be an interface between existing electronic structure codes and kinetics codes. Consideration may be given to: energy transfer and dynamic processes at interfaces and in condensed phases; the effects of solvation; and the potential non-adiabatic nature of chemical reactions. Approaches utilizing direct dynamics methods are encouraged. Emphasis shall be placed on both the computational efficiency of the code as well as the accuracy.

PHASE I: Demonstrate capability to calculate kinetic rate constants for chemical reactions in condensed phase materials from electronic structure theory inputs. Estimate error based on level of quantum theory used. Develop a plan for seamless integration of electronic structure and kinetics calculations.

PHASE II: A seamless, integrated computer code shall be developed to permit the accurate calculation of rate constants for chemical reactions in condensed phases based on electronic structure calculations. The code should be computationally efficient and should contain a user interface that permits easy use of the program by personnel who are not experts in computational chemistry.

PHASE III / DUAL USE: Military application: New materials will also be able to be more quickly designed and synthesized in bulk. By predicting reactive behavior, materials can be designed to various military applications. Commercial application: The approach will be useful for commercial and research applications in materials, CVD, plasma and combustion chemistry applications including the automotive, aerospace, and electronics industries.

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KEYWORDS: Computational Chemistry, Kinetics, Rate constants

AF08-BT20 TITLE: Scalable technology for growth of high quality single crystal gallium nitride

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop and demonstrate a scalable, cost-effective approach for large-scale manufacturing of single crystal gallium nitride for electronic and photonic devices.

DESCRIPTION: Gallium-nitride-based electronics are needed to advance a number of high performance capabilities for the Air Force, including photodetectors, high efficiency solid state lasers and other light emitters, power switching devices, and RF power amplifiers. The development of these capabilities is currently hampered by the absence of suitable bulk GaN substrates. While considerable progress has been made with heteroepitaxial GaN-based devices, true homoepitaxial devices are needed to advance U.S. capabilities to the next level. Pseudo-bulk GaN wafers, grown by hydride vapor phase epitaxy (HVPE), are available commercially, but the crystalline quality is insufficient for a number of Air Force applications and a lower cost would be highly desirable. Ideally what is required is a true bulk crystal growth method, scalable to large quantities and capable of cost-effective growth of high quality gallium nitride boules with a dislocation density below 10E4 cm-2.

A number of groups have demonstrated growth of GaN crystals using a flux, such as molten Ga, Ga-Na alloys, or inorganic salts. In some cases excellent crystallinity has been demonstrated, with dislocation densities well below 104 cm-2. However, scaleup of these approaches has been very difficult. Limiting factors include: low solubility of the flux for gallium and/or nitrogen; low diffusion coefficient for dissolved species in the flux; or requirement for a high nitrogen pressure, which limits the practical size of the apparatus. Potentially useful approaches might identify new flux compositions with high solubilities for both gallium and nitrogen, favorable transport characteristics, and modest gas pressure requirements.

Other groups have demonstrated ammonothermal growth of GaN. By analogy to quartz and other hydrothermal crystal growth processes, this approach is expected to be scalable to large volumes, so that many crystals could be grown in a single run. And, in some cases, excellent crystallinity has been demonstrated, with dislocation densities well below 104 cm-2. However, in most cases the reported growth rates are quite small, about 1-4 microns per hour, and it is difficult to imagine a large scale manufacturing process with such low growth rates. Higher growth rates have been reported for a process operating at higher pressures, using apparatus adapted from high pressure high temperature diamond growth. However, it is unclear how such an approach would be scaled up to large volumes. Potentially useful approaches might demonstrate new chemistries that give superior growth rates at pressures and temperatures accessible with conventional hydrothermal equipment, or alternative apparatus that is scalable to large volumes and enables higher growth rates at higher pressures and/or temperatures.

PHASE I: Develop a methodology for high rate scalable GaN crystal growth. Enhanced chemical processes and novel apparatus configurations for improved growth kinetics should be investigated. Apparatus design and engineering schematics, should be completed by the end of Phase I.

PHASE II: Demonstrate feasibility and scalability of bulk GaN crystal growth process, by building and testing apparatus designed in Phase I. Validate methodology developed in phase I with reproducible growth of greater than 1 inch diameter GaN crystals with dislocation densities below 10E4 cm-2.

PHASE III / DUAL USE: Military application: Solar-blind detectors, lasers, power amplifiers. Commercial application: High-brightness light-emitting diodes, laser diodes.

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KEYWORDS: Gallium nitride, bulk crystal growth, dislocation density, high pressure, ammonothermal, flux growth

AF08-BT21 TITLE: High-Temperature Environmental Barrier Coating for Silicon Carbide Composites

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Identify and demonstrate an environmental barrier coating for silicon carbide fiber-reinforced silicon carbide matrix composites.

DESCRIPTION: Silicon carbide fiber-reinforced silicon carbide ceramic-matrix composites (SiC/SiC CMCs), by virtue of low density and high-temperature capability, are prime candidates for turbine engine hot-section components. However, they are thermodynamically unstable in combustion environments. Not only are they susceptible to oxidation, but the silica oxidation product, which initially forms a passivating film, volatilizes in the presence of water vapor at high temperatures and pressures. To minimize SiC and SiO2 recession due to volatilization, environmental barrier coatings (EBCs) have been developed to protect the substrate from the combustion gases. While minimizing the effects of environmental degradation, it is unknown whether current EBCs are capable of protecting CMCs over their intended design life of approximately 2000 h in the combustion environment of advanced turbine engines, where component surface temperatures are predicted to reach in excess of 3000°F. Furthermore, EBCs are expected to function as a thermal barrier coating to maintain a 2700°F interface temperature for cooled CMC components. Innovative materials and process solutions are sought for increasing the temperature capability of EBCs for SiC/SiC CMCs at elevated temperatures in combustion environments. The offeror should conduct a detailed literature search to identify key issues associated with the development of a novel EBC. Selection and processing of a successful EBC and any bond coat will be strongly influence by the fiber and matrix constituents of the CMC substrate; therefore, teaming with a CMC manufacturer is highly recommended.

PHASE I: Identification and proof of concept of an EBC on a model silicon carbide composite in a simulated combustion environment.

PHASE II: Demonstration and optimization of an EBC on a fiber-reinforced SiC/SiC CMC. Demonstrate temperature capability of 3000°F with 300°F through-thickness thermal gradient and protection of the CMC substrate from recession under thermal cycling in simulated environment at a surface temperature of 3000°F. Successful EBC performance will correspond to life times on the order of 2000 h.

PHASE III / DUAL USE: Military application: Technologies developed should be made available to turbine engine companies. SiC/SiC CMCs are applicable to engine hot-section components such as combustors, turbines, and exhaust components Commercial application: SiC/SiC CMCs are in development for commercial and industrial applications such as power turbines and commercial aircraft engine components.

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KEYWORDS: Ceramic matrix composite, silicon carbide, coatings, environmental degradation, oxidation

AF08-BT22 TITLE: Oxide Heterostructure-Based Nanoelectronics Devices

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Explore the possibility to design and fabricate ultra-high density memory and logic in LaAlO3/SrTiO3 heterostructures.

DESCRIPTION: The recent discovery of a high-mobility two-dimensional electron gas at the interface between a polar oxide (LaAlO3) and a non-polar oxide (SrTiO3) has fueled significant interest in oxide-based electronics. The interface between these materials has been shown to be switchable between a metallic and insulating state when the LaAlO3 thickness is exactly 3 unit cells [1]. Most interesting for technological applications is the recent discovery that the conductance of this interface can be patterned at scales approaching one nanometer using a conducting atomic-force microscope (AFM) probe [2]. A number of applications are envisioned based on this latest discovery, including ultra-high density memory and logic, as well as electronic functionality based on single electrons. Scaling of this invention may require use of millipede technology or other non-AFM-based approaches.

The objective of this STTR effort is to develop key materials processes that will enable ultra-high-density logic and memory operations in this novel physical system. Directions of interest include the development of reliable methodologies for producing high-quality oxide heterostructures, reliable high-density methods for producing ohmic contact to the LaAlO3/SrTiO3 interface, and demonstration of prototype memory and transistor designs.

PHASE I: Based on published results and preliminary experiments, select the most promising methods for ultra-high-density information processing applications using the class of heterostructures described above.

PHASE II: Build prototype memory and/or logic circuits of medium integration scale and optimize their performance. Develop new electronically addressable memory architectures and transistor designs scalable to sub-10-nm integration density.

PHASE III / DUAL USE: Military application: Oxide-based nanoelectronics may enable ultra-high density integration of reconfigurable logic and non-volatile memory with impact for lightweight low-power computing needs in land air & space vehicles Commercial application: Development of nanoscale memories and transistors may be applied to consumer electronics, sensitive charge detection, and biomedical applications.

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KEYWORDS: oxide nanoelectronics; two-dimensional electron gas; nanodevice; nanosensor; memory; millipede; non-volatile memory; reconfigurable logic; digital electronics; single-electron devices

AF08-BT23 TITLE: Health Monitoring of Composite Structures Using Carbon Nanotubes

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop composite structures which incorporate carbon nanotubes to realize inherent capabilities for in-situ monitoring of damaging effects such as delamination, cracking and fiber rupture.

DESCRIPTION: Carbon nanotubes offer distinct multifunctional features for use in sensors, structures, actuators, and other applications. The piezoresistive attributes of carbon nanotubes and the electrical conductivity of multi-walled nanotubes are among the features encouraging their use toward sensing and health monitoring applications. The fine geometry of carbon nanotubes allows for distributed, three-dimensional alteration of composite properties. The highly desirable mechanical attribute and the tremendous specific surface area of carbon nanotubes greatly benefit their reinforcing effects in composites. Polymer composites incorporating carbon nanotubes can realize self-sensing qualities for health monitoring applications at relatively low nanotube volume fractions. The three-dimensional (homogeneous) effects and volumetric distribution of nanotubes in composites facilitate large-area detection of diverse damaging effects with different orientations. The fine geometry and high surface area of nanotubes pose important challenges to their processing into composites. Other challenges in development of composites incorporating carbon nanotubes for health monitoring purposes relate to the specific properties to be monitored and the interpretation of these properties for identification of the type and extent of damaging phenomena in composites.

PHASE I: Develop and implement a strategy for using carbon nanotubes toward health monitoring of composite structures. Verify the potential to monitor the type and extent of the prevalent damaging phenomena in composites while retaining or improving their desirable engineering properties.

PHASE II: Refine and optimize the composite structure incorporating carbon nanotubes for effective health monitoring while achieving a desirable balance of engineering properties. Evaluate and improve the health monitoring attributes of the system under major load and environmental effects. Evaluate the impact of the technology on the initial and life-cycle cost of composite structures.

PHASE III / DUAL USE: Military application: Development of composites with inherent health monitoring capabilities would enhance the safety and life-cycle cost of composite structures in military air vehicles, and also in land and sea vehicles Commercial application: The technology would benefit the growing range of commercial air, land and sea vehicles, infrastructure and other systems which are making increasing use of composites.

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KEYWORDS: Health Monitoring, Composite Structures, Carbon Nanotubes

AF08-BT24 TITLE: Nonlinear Signature-Matched Hyperspectral Change Detection

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Investigate nonlinear signal processing methods for detecting changes in hyperspectral image data between successive observations.

DESCRIPTION: The ability to remotely detect military targets hidden in background clutter such as foliage and urban areas is of great interest to the Air Force. By exploiting specific signature content of targets relative to background clutter materials, hyperspectral imaging presents one promising method for achieving this capability. Unfortunately, the great diversity of materials in realistic background areas often results in false alarm rates that are higher than desired. By imaging areas successively over time, change detection presents a promising discrimination method for detecting changes in target state (e.g., insertion, deletion, or movement of targets) with a lower false alarm rate. Prior research has provided a proof-of-concept of hyperspectral change detection utilizing linear prediction methods such as chronochrome and covariance equalization. These approaches are generally limited in several ways. One significant limitation to these methods is the use of a simple, space-invariant, affine model of background change. The background changes occurring are often quite complex and cannot be accurately modeled or predicted in a linear fashion. In addition, simple anomaly detectors used in conjunction with the linear predictors assume a Gaussian distribution for the data which is often invalid. Other limitations of current change detection algorithms include reliance on fine, sub-pixel registration between successive images that is difficult to achieve in practice and the detection of anomalous change without regard to the specific spectral character of the change.

The focus of this effort is to explore novel change detection methods that specifically address the aforementioned limitations of the current state-of-the-art utilizing nonlinear signal processing methods. These methods potentially provide an avenue for modeling complex nonlinear background changes through the use of projection kernels or other such techniques. Non-linear algorithms typically prove difficult to implement on high-dimensional data, such as hyperspectral images, due to computational complexity. While these techniques present a higher risk, prior work, such as the kernel RX algorithm, has shown promising results. The signal processing methods should capture possible space-variant and non-linear temporal changes between hyperspectral images (e.g., changes in shadowing), and should support high clutter rejection even in the presence of unknown misregistration between images. Furthermore, the detection of specific target state changes is of prime interest to this topic as opposed to non-specific, anomalous changes. Such signature-based methods should be able to incorporate both laboratory and in situ spectral signature data.

PHASE I: Theoretical foundation for novel hyperspectral change detection process addressing limits of state-of-the-art with non-linear processing methods. Develop baseline processing algorithm/perform proof-of-concept experiment with realistic hyperspectral imagery to establish inherent effectiveness.

PHASE II: Refine the baseline processing algorithm into a robust hyperspectral change detection process for hyperspectral imagery from various sources. Thoroughly evaluate the detection performance as a function of operating conditions. Implement the algorithm on a computing platform that supports turn-key operation by a moderately trained image analyst.

PHASE III / DUAL USE: Military application: Target detection, security monitoring, remote environmental sensing. Real-time implementation on air-borne or satellite-based systems. Commercial application: This technology can support civil remote sensing applications such as climate change monitoring and agricultural remote sensing, as well as law enforcement and border surveillance applications.

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KEYWORDS: hyperspectral, change detection, remote sensing, target detection, non-linear, processing

AF08-BT25 TITLE: Electrical power generation for sustained high speed flight

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: Develop approaches to generate electrical power sufficient to support scramjet-powered vehicle subsystems using available flow energy as opposed to stored energy.

DESCRIPTION: On-board electrical power for a scramjet-powered vehicle is required for sustained, hypersonic flight. Currently in programs such as the X-51, the required power is provided by batteries. For the expected 5 minute flight, this is an acceptable approach. For scramjet powered platforms – space access, strike and ISR vehicles and even long-range cruise weapons – a revolutionary approach is required for on-board power generation to efficiently satisfy electrical power requirements. For these anticipated applications of the engine technology, flight durations are expected to be much longer and batteries either fail to meet the projected need for electrical power or are precluded by system mass and volume constraints. The flight regime of primary interest for these systems is flight Mach numbers from 4 to 8, and dynamic pressure from 25-100 kPa. In addition to current alternatives of interest such as magnetogasdynamic (MGD) power extraction, fluidic heat exchange, and thermoelectric energy conversion (TEC), proposers are encouraged to consider new strategies that generate electrical energy from “wasted” heat energy, i.e. heat otherwise absorbed by the structure and/or radiated to space. However, significant advances or novel approaches in more established fields will be considered. As an example, TEC materials are needed that are compatible with the structural and environmental requirements of a large scramjet powered vehicle. For all technology approaches, system efficiency in terms of power density should be comparable to conventional batteries, fuel cells, or other stored energy systems.

PHASE I: Develop continuous 100 Kw power generation capability based on 5 kg/s engine air flow and 0.7 phi. The concept should be scalable with engine size. Provide system level analysis demonstrating power output and compatibility with typical hypersonic vehicle size/weight constraints and environment.

PHASE II: Develop prototype design for ground test evaluation to demo power generation and other constraints including compatibility with relevant vehicle/engine/fuel system structures and operating environment; power system weight/volume; and range of operability with variation in flight and engine conditions. Design should target a specific test (model and ground facility) for the evaluation.

PHASE III / DUAL USE: Military application: Scramjet supports weapon and space access applications where speed and high specific impulse are highly valued for range and payload mass fraction. Power gen capability is required for this system. Commercial application: Scramjet engines support more affordable space access with higher payload mass fraction and flexibility in orbit selection. Power generation capability is required for this application.

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KEYWORDS: scramjet, electrical power generation, hypersonic, magnetogasdynamic, thermoelectric energy conversion, fluidic heat exchange

AF08-BT26 TITLE: Frequency agile terahertz detectors

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Develop a compact, light weight, tunable, THz detector for spectroscopic applications.

DESCRIPTION: Tunable detectors operating in the terahertz (THz) region of the spectrum (0.5-5THz) have the potential to be used as UAV mountable or man-portable spectrometers. Such spectrometers would be an invaluable aid to chemical and biological threat analysis/detection in both close-in support and long standoff scenarios. As an example, it has been demonstrated that THz radiation, along with a grating coupler, can be used to excite plasmon modes in a two dimensional electron gas (2deg)[1]. These resonant charge density oscillations have also been shown to produce changes in the transistor transconductance of high electron mobility transistors (HEMT)[2]. The coupling grating has the additional function of acting as the transistors gate, thereby allowing voltage tunability of the 2deg sheet charge density and, in turn, tuning of the allowed plasmon resonance. This type of device represents a new class of plasmon based THz detector and has been envisioned for use as a true "spectrometer on a chip". The goal is to develop a narrow band (FWHM<1cm-1) THz detector which can be tuned over at least a 1THz bandwidth. This device should be small (<1 cm3), have the potential for being fabricated into an array format and have a minimum operating temperature of >50K. Although a plasmon device was used as an example, other ideas will considered such as MEMs and/or nano-structured optical components. Approaches addressing long-term reliability and maintenance-free operation of proposed THz detector are highly encouraged.

PHASE I: Demonstrate the feasibility of the approach to tunable THz detection. This includes a clear understanding of device temperature characteristics, tunability range and central detector frequency as well as temperature effects. Demonstrate THz detection. Perform design of components to implement in Phase II. Develop preliminary design for devices use in a spectroscopic application applicable to Air Force needs.

PHASE II: Build upon Phase I and demonstrate tunable detection of a narrowband source. Perform analysis, characterization, and optimization of system including determination of minimum detectable signal, overall system resolution and maximum operating temperature. Demonstrate resolving power.

PHASE III / DUAL USE: Military application: Explosives and chemical agent detection, non destructive evaluation , high sensitivity detection of thermal bodies, and flame spectroscopy. Commercial application: Atmospheric environment sensing, near object detection, security, material imaging and inspection, quality control will benefit from new technology in this part of the electromagnetic spectrum

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KEYWORDS: terahertz, THz, frequency agile detector, plasmonic, nano-structures

AF08-BT27 TITLE: Real-time In-situ Impact and Damage Locator in Anisotropic Aerospace Structures

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: To develop a device based on low-cost, permanently-attached sensors for locating impacts and/or growing damage in anisotropic aerospace structures.

DESCRIPTION: Aerospace structures are evolving to include lightweight, high-performance materials such as polymer-matrix or ceramic-matrix composites. For example, in the commercial sector a substantial portion of the new Boeing 787 and Airbus A380 contains composites. These materials generally result in an anisotropic mechanical behavior. At the same time, the presence of stiffeners or multiple layers (e.g. thermal protections systems) in the structure's fuselage can contribute to making the structural assembly macroscopically anisotropic. In these cases the well-known technique based on the triangulation of Acoustic Emission (AE)-type waves, passively detected by multiple sensors, can lead to large errors in the location of impacts or active damage. The errors arise since the conventional AE location is based on time-of-flight information of the waves traveling from their source location to the sensors, which either assumes a constant wave velocity in every direction (i.e. isotropic structures), or it requires prior knowledge of the direction-dependent wave velocity for anisotropic structures.

A more accurate and robust prototype should be devised to locate impact or growing damage in complex anisotropic structures.

Desirable requirements of the prototype are:
1) the ability to locate impact/damage without prior characterization of the anisotropic behavior of the structure (i.e. without knowledge of the direction-dependent wave velocity);
2) the use of permanently-attached, durable, low-power and low-cost sensors;
3) the ability to provide impact/damage detection and location in real-time, rather than in a post-event inspection mode.

Phase I efforts should consist of a demonstration of hammer impact locations in simple geometries including flat aluminum panels, aluminum panels with attached stiffeners and anisotropic polymer-matrix composite laminates.

PHASE I: Feasibility study on simple geometries, from flat aluminum panels to anisotropic polymer-matrix laminates. Demonstration of location of hammer impacts. Sensor design/selection and basic programming of location algorithm.

PHASE II: Demonstration of location of growing damage in phase I panels. Extension of impact and damage location in more complex components, including multilayered assemblies and composite-to-composite joints. Full development of location prototype and preparation of recommendations for prototype use.

PHASE III / DUAL USE: Military application: Self-monitoring and self-diagnosis of anisotropic aerospace structures used by USAF flying platforms as well as by other military agencies (Army, Navy, Marines, Border Patrol, Coast Guard, etc.) Commercial application: Civilian aerospace applications that are increasingly using composite materials in passenger and cargo aircraft (e.g. Boeing 787, Airbus A380, etc.).

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KEYWORDS: composite materials, impact detection, damage detection, acoustic emission, source location, anisotropic structures, smart structures, sensor networks.

AF08-BT28 TITLE: Reconfigurable Materials for Photonic Systems

TECHNOLOGY AREAS: Materials/Processes

OBJECTIVE: Develop optical mechanisms in nano-structures for digitally controlled change between two or more states enabling programmable Reconfigurable Cellular Electronic and Photonic Arrays(RCEPAs).

DESCRIPTION: RCEPAs are of interest to the Air Force due to their great potential for directly implementing complex systems as software-defined emulations, configuring pre-built (but uncommitted) logic, interconnect, switching, memory and other resources to perform a desired set of functions. The success in design, utility, and implementation of RCEPA systems is tightly coupled to the materials and geometries used in these basic device cells, as well as the choice of layout and interconnect of such device elements to serve as a switch array. RCEPAs are malleable and, conceptually, infinitely reformable. In this program, new classes of reconfigurable photonics are expected to result in revolutionary expressions of pervasive morphability in warfighting systems of relevance to Air Force interests.

PHASE I: Investigate, analyze and design new multi-state/continuously controlled optical reconfigurability mechanisms in novel materials and micro- and nano-microelectro(opto)-mechanical (NEM/MEM/NOEM/MOEM) structures.

PHASE II: The proposed design concept, and pertinent material and/or the relevant material processes shall be further developed, and the device functional properties and its usefulness for commercial and military applications shall be fully demonstrated. All necessary manufacturing processes for commercialization of the material and/or product shall be developed as well.

PHASE III / DUAL USE: Military application: Follow-on activities are expected to be pursued by seeking opportunities for integrating the improved reconfigurable materials into photonic-based switching systems for USAF systems. Commercial application: Commercial benefits would be for optical signal processing in telecommunications and scientific instruments.

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KEYWORDS: photonic switching, optical reconfigurability, slow light, light signal processing

AF08-BT29 TITLE: Affordable Structures Using Advanced Machining Techniques

TECHNOLOGY AREAS: Air Platform

OBJECTIVE: The objective of this program is to increase the affordability of machined titanium aircraft structures.

DESCRIPTION: Approximately 30% of the cost of making a titanium structural component is consumed during the machining. This is mostly due to titanium hardness, strain rate sensitivity and modulus. By comparison titanium has a removal rate two orders of magnitude slower than aluminum. Cost and lead time of titanium parts can be reduced if the removal rate of titanium can be improved. Solutions are sought to increase the removal rate of titanium to enable lower cost high performance aircraft structures. Multiple technologies could be combined to achieve greater reductions.

PHASE I: Demonstrate feasibility of removal rate reduction in common titanium structures.

PHASE II: Demonstrate the effect of technology on properties, if any. Identify and demonstrate methods of machining that could be employed with this new approach. Identify impacts to current methods, barriers to implementation and schedule for introduction.

PHASE III / DUAL USE: Military application: The structural technology developed will be applicable to aircraft structures such as F-35, F-22, future aircraft and other military vehicles. Commercial application: The technology developed will be applicable to commercial aircraft.

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KEYWORDS: titanium, aircraft structures, titanium cost, machining techniques

AF08-BT30 TITLE: Instrumentation for Nanoscale Spectroscopy

TECHNOLOGY AREAS: Sensors

OBJECTIVE: Development of nanoscale spectroscopic imaging techniques providing chemically-specific information.

DESCRIPTION: Imaging techniques, such as scanning tunneling microscopy, electron microscopy, or atomic force microscopy, provide high spatial resolution but their chemically-specific information is limited if no prior information about the nature of the sample is available. At best, these techniques provide information about the elemental composition, e.g. 90% carbon and 10% oxygen. However, chemical information is associated with the bonds between atoms and the structure in which the atoms are embedded. High chemical specificity is attained with nuclear magnetic resonance (NMR) but the spatial resolution is limited because of the weak signal associated with a single nuclear spin. Two optical techniques, infrared absorption and Raman scattering (and their nonlinear derivatives), provide chemically-specific fingerprints in the form of vibrational spectra and are widely used for quality and process control in the pharmaceutical and food industries. Unfortunately, the attainable resolution is limited by diffraction to about 250nm. The objective of this program is to develop new instrumentation and techniques for chemically-specific imaging with high spatial resolution. The goal is to achieve a high product of spatial resolution and chemical specificity without using substantial prior information about sample composition.

PHASE I: Develop an instrument platform for nanoscale spectroscopic imaging. The system will be capable to achieve sub-100nm resolutions and acquire chemically-specific spectra in times of ~ 1-100 ms per pixel.

PHASE II: Implementation of nanoscale hyperspectral imaging. Each image pixel will be assigned entire spectra. All data will be stored during image acquisition and can be later visualized. Data processing based on principal component analysis will be implemented to extract maximum information.

PHASE III / DUAL USE: Military application: The ability to characterize materials and devices on the nanoscale is of paramount importance to our national security, e.g. increased capability to screen for and reverse engineer high energy density materials, radar absorbing materials, biologically active nano-systems, and nuclear nanomaterials. Commercial application: Vibrational spectroscopy (Raman, IR) is widely used in the pharmaceutical and food industries for quality and process control. Being able to extend ‘chemical fingerprinting’ to the nanometer scale will enable wide-ranging applications, e.g. semiconductor failure analysis, biosensing, catalysis, and cellular diagnostics.

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KEYWORDS: Chemical imaging, vibrational spectroscopy, scanning-probe microscopy, Raman spectroscopy, infrared spectroscopy, hyperspectral imaging, nanospectroscopy, nanoprobe, nanoscience