REPORT DOCUMENTATION PAGE

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8. PERFORMING ORGANIZATION REPORT NUMBER
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13. ABSTRACT (Maximum 200 words)

The final results and status of the 9 projects [see below], that were previously reviewed during a face-to-face meeting on 15 November 2004 in Adelphi, Maryland, are attached to this cover sheet.

- *Characterization of AlGaN Active Regions*
- *Integration of Laser Drivers with VCSEL Arrays – Phase II*
- *Development of Hard Photoresist Masks Using Photoinduced Compositional Changes*
- *Robust Micro-Electro-Mechanical-Systems [MEMS]*
- *InAs/GaSb Type-II Super Lattices: Non-linear Optical Effects*
- *HgCdTe on Si through Nanometer-thin, Strain-relieving SiO_2 Buffer – Phase 2*
- *Nanoheteroepitaxial Substrates for Growth of GaN on Sapphire*
- *Flexible AM-OLED Displays on Metal Foils*
- *Image Fusion Research for CWD and Night Vision*

14. SUBJECT TERMS
AlGaN; UV Lasers; VCSEL arrays; Photoresist; MEMS; Quantum Dots; HgCdTe; GaN; Flexible Displays; Night vision

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Characterization of *AlGaN* active regions
Dr. Volkmar Dierolf, Dr. Slade Cargill, Dr. Mike Stavola

Scientific Progress and Accomplishments:
This project was an independent project in the fiscal year 2003 and is now part of the Wide Band Gap Semiconductor thrust.

Carrier localization through composition fluctuations or strain is essential to achieve high emission quantum efficiency in layers that still have a large number of structural defects. We use and developed optical characterization techniques and study samples grown by ARL and at Penn State University to find regions with carrier localization and understand the physical mechanism. We further explore incorporation sites of

Summary:

- AlxGa1-xN epitaxial layers on sapphire exhibit intense room-temperature emission redshifted by about 20nm with respect to the NBE
- LED has been demonstrated
- Time-resolved PL-data and CL mapping indicated excitation transfer from free excitons into radiative localized states
- Several localized states exist and the emission peak positions vary across the sample
- Samples with the localization effect show characteristic morphology which however is not directly correlated with CL intensities features
- Localization effect is not limited to the surface
- Compositional variations are small on a 500nm length scale

Continuing work:

- Clarify mechanism of localization
  - Increase spatial resolution of PL (NSOM, possibly at low T)
  - Implement spectral imaging in the CL system
  - T-dependence of localization features
  - Improve spatial resolution in Raman mapping (325nm)
- Characterize role of patterned sapphire substrates and /or low defect concentration substrates or templates to improve radiative efficiencies on the localized layers

Scientific Personnel:
A. Yu. Nikiforov, C. Sandmann, Z. Fleischman, P. Capek
A. Steckl [ARO], J. Zavada [ARO]

Publications, Patents, & Papers:
1 paper at Fall MRS meeting 2003
2 joint papers at Fall MRS meeting 2004
1 joint paper at Army Science Conference 2004
Paper submitted to Applied Physics Letters

Report of Invention:
na

Technology transfer:
na

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Integration of Laser Drivers with VCSEL Arrays – Phase II
Dr. James Hwang

Scientific Progress and Accomplishments:

Project Summary: To optimize both VCSELs and VCSEL drivers for increased speed, efficiency, temperature range and integration level. Milestones: Q1-refined VCSEL model, Q2-10 Gb/s VCSEL, Q3-redesigned laser driver, and Q4-quantum-dot VCSEL.

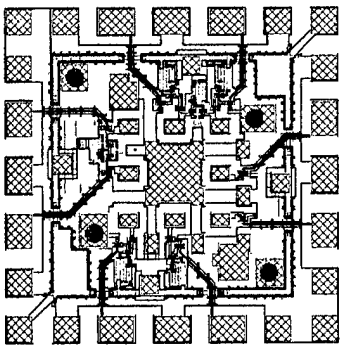
Project Status: VCSEL models were refined and used to redesign the laser driver for increased integration and decreased crosstalk. High-speed VCSELs were designed and the material was grown and delivered to ARL.

Scientific Results:

- Long R-C time constant of VCSEL was found to limit the system speed. Suggested that ARL reduce VCSEL contact resistance.
- Driver circuit with auxiliary current source was designed to overcome the slow VCSEL speed, with potentially 30% improvement.
- Crosstalk between VCSELs was suppressed with careful design of supply and ground lines and shunting resistors and capacitors.
- Internal waveform probing was facilitated for design verification/debugging.
- RF probable VCSELs and calibration patterns were designed to facilitate high-frequency characterization.

Continuing Activities:

- High-speed, large-signal testing of laser driver
- VCSEL/driver redesign & optimization
- Driver crosstalk characterization and research
- Laser driver and VCSEL integration
- Quantum-dot VCSEL



Layout of 3X3 VCSEL Driver

Scientific Personnel:
Dr. James Hwang

Publications, Patents, & Papers:
na
Report of Invention:
na
Technology transfer:
na

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(Continuation Sheet)

Development of Hard Photoresist Masks Using Photoinduced Compositional Changes

Dr. Himanshu Jain

Scientific Progress and Accomplishments:

Project Objective: To develop photoresist mask technology for MEMS applications currently being pursued at ARL such as PZT piezoelectric elements and the '3-D' turbine structures for power generation.
The proposed technology is new to the ARL process, making use of the unusual photosensitive properties of chalcogenide glasses. The focus is on testing the chalcogenide glass photoresists with reactive ion etching (RIE). Further, we will explore compositionally altered photoresists as a new paradigm of photoresist technology, especially in relation to RIE.

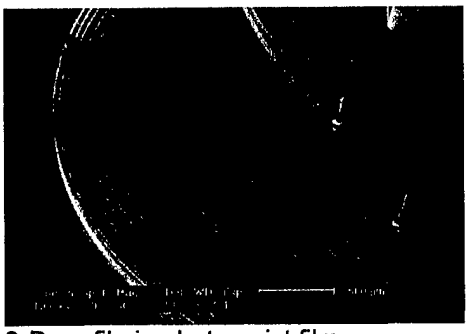
Results:

1. Nanolithography state-of-art: It's polymers!
   - ❖ PMMA organic resist associated with pattern transfer techniques like lift off and reactive ion etching (RIE):
2. Monogranular lines of 5-nm width

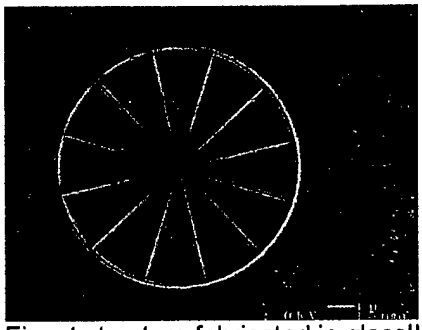
   30-nm pitch pillar arrays after lift-off and RIE ⇒ 700 Gbit/in2 storage!
   - ❖ At present e-beam is perhaps the most developed means of nano-scale writing.
   - ❖ Limited to surface writing.
   - ❖ Writing with a single electron beam is quite slow, not compatible with mass production. However, mold by EBL + nano imprint lithography with replication fidelity of 6 nm ⇒ Mass production of sub-10 nm structures is feasible.
   - ❖ Inorganic glasses should give higher resolution compared to polymers for two reasons:
     - ➢ Polymers are made of much larger, long chain molecules
     - ➢ Polymers consist of light elements: Greater region of unwanted electron scattering
     - ➢ Inorganic glasses are much harder than polymers and hence resistant to unwanted etching ⇒ Better hard masks.v~Prepare large surfaces, both planar and non-planar, by vacuum evaporation method, PECVD or RF sputtering. Exceptionally thin (10s nm) and uniform film of photoresist for selective etching of SiO2, Si, Cr : Better control of geometry.
     - ➢ No need of pre-baking and post-baking
     - ➢ Simple control from positive to a negative lithographic process: Same photoresist, just change the composition of the developer

Conclusions:

1. Demonstrated a contrast in etch selectivity for As2S3
   Ag doped region produces a negative dry photoresist.
2. There appears to be a linear relationship between light exposure and differential etching.
3. Chalcogenide glasses show promise for gray hard mask for 3-D lithography



3-D profile in photoresist film.



Finest structure fabricated in glass!!

Scientific Personnel:
Dr. Himanshu Jain, Miroslav Vlcek, Lauren Russo

Publications, Patents, & Papers:
na

Report of Invention:
na

Technology transfer:
na

REPORT DOCUMENTATION PAGE (SF298)
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Robust Micro-Electro-Mechanical Systems
Dr. Rick Vinci, Dr. James Hwang

Scientific Progress and Accomplishments:
Project Objective:
To investigate innovative approaches that enable revolutionary advances in science and devices of MEMS, with the ultimate objective being the realization of micromechanical devices capable of operating under harsh conditions - e.g., under large temperature excursions, large power throughputs, high g-forces, presence of corrosive substances, etc. - while maintaining unprecedented performance, stability, and lifetime.

Project Tasks:
Test Procedure Development and Refinement
Accelerated Life Tests
Development of Novel Metal Alloys and Dielectrics

Project Emphasis:
Novel Pt-based electrodes for PZT MEMS devices
Stable metal films for reflective optics

Accomplishments:
Fabricated novel Pt-IrO2 alloys
demonstrated improved alloy mechanical performance
implemented new "capacitance bulge" test
characterized significant anelastic behavior in metal films
developed model to describe anelastic response

Scientific Personnel:
Dr. Rick Vinci, Dr. James Hwang, Richard Chromik, Seungmin Hyun, Thirumalesh Bannuru, Walter Brown

Publications, Patents, & Papers:
R.P. Vinci, Creep in nanometer thickness Al films, THERMEC, Madrid, Spain, July, 2003.
R.P. Vinci, Alloying effects on mechanical behavior of thin films, AVS Annual Meeting, Baltimore, MD, October, 2003.
R.P. Vinci, Creep in nanometer thickness Al films, ASME National Congress, Washington, DC, November, 2003.
R.P. Vinci, Mechanical behavior of nanometer scale thin films, TMS Annual Meeting, Charlotte, NC, March 2004.
R.P Vinci, Effects of Alloying on Strength and Residual Stress of Pt-based Thin Films, Army Research Laboratory, Adelphi, MD, June, 2004.
R.R. Chromik, T. Bannuru, and R.P. Vinci, Internal oxidation and mechanical properties of Pt-IrO2 thin films, Proc. Mater Res. Soc. Symp., 2003, U8.13.1-6.
S. Hyun, W.L. Brown, and R. P. Vinci, Stress relaxation in nanoscale aluminum films, Proc. SPIE, 5343, 2004, 154-162.
S. Hyun, W.L. Brown, and R. P. Vinci, Thickness and temperature dependence of stress relaxation in nanoscale aluminum films, Appl

Report of Invention:
na

Technology transfer:
na

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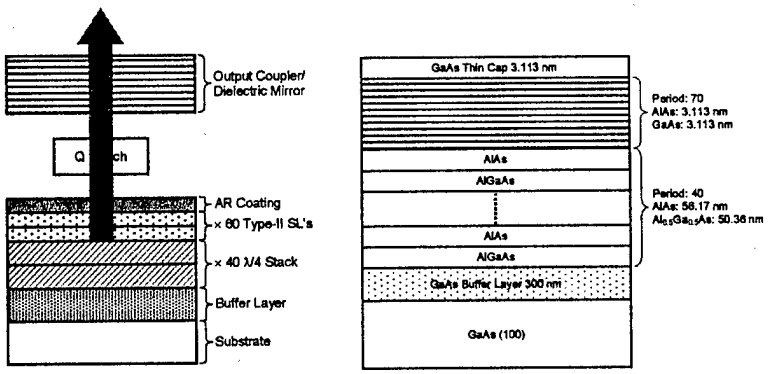
InAs/GaSb Type-IISuper lattices: Nonlinear-Optical Effects
Dr. Yujie Ding

Scientific Progress and Accomplishments:

- GaAs/AlAs superlattices with a range of layer thicknesses – grown and studied
- Quasi-indirect, quasi-direct, phonon-assisted quasi-indirect transitions – observed and explained
- Quasi-direct PL intensity – dramatically enhanced by increasing temperature or pump intensity due to resonant phonon-assisted $X\Gamma \rightarrow$ intervalley up-transfer of electrons – modeled
- Recombination of free and localized excitons – studied $\Rightarrow$ dissociation of free excitons – observed; energy required to bind free excitons to interface traps – measured
- Amplification of PL evanescent wave by optical pumping – achieved
- Design of type-II GaAs/AlAs SL's – further optimized for Q-switched laser

Conclusions:

- Anomalously strong band-filling effects – observed: Define linear-response range of mid-IR detectors and output powers of mid-IR emitters
- Dependence of band-filling effects on GaSb & InAs widths – investigated
- Dependence of integrated PL intensity on pump intensity – studied: Radiative recombination vs. nonradiative recombination at interface & barrier traps and Auger
- Effect of defect density on PL spectrum – investigated
- Comparison between photocurrent & PL spectra – made



Optimized GaAs/AlAs Structure for Q-Switched Laser.

Scientific Personnel:
Dr. Yujie J. Ding, Dr. John Little [ARL], Dr. Dwight Woolard [ARO]

Publications, Patents, & Papers:

- One paper submitted to IEEE J. Quantum Electron.
- One paper presented at CLEO 2004

Report of Invention:
na
Technology transfer:
na

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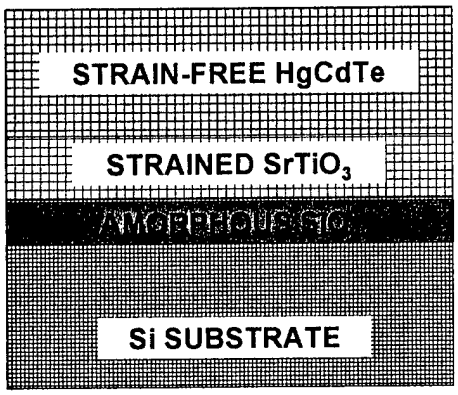
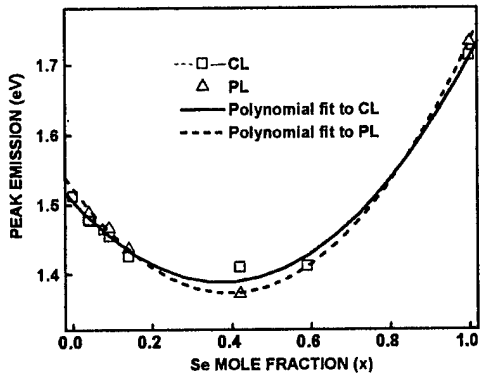
HgCdTe on Si through Nm-thin, strain-relieving SiO2 Buffer – Phase 2
Dr. Jim Hwang

The objective of this project is to explore the unconventional approach of growing HgCdTe on Si through a nanometer-thin, strain-relieving SiO2 buffer layer. To this end, four tasks were planned: 1) BaTiO3 grown on Si, 2) CdTe grown on BaTiO3/SiO2/Si, 3) CdTe/BaTiO3/SiO2/Si characterized, and 4) HgCdTe grown on BaTiO3/SiO2/Si.

Scientific Progress and Accomplishments:
BaTiO3 was grown on Si by Penn State University and are awaiting HgCdTe overgrowth at ARL. CdTe was grown by ARL on GaAs/SrTiO3/SiO2/Si previously grown by IQE. To develop the techniques for characterizing these layers, CdSeTe grown by ARL on Si were characterized at Lehigh by using atomic-force microscopy, secondary-electron microscopy, photoluminescence, cathodoluminescence, and wavelength-dispersive x-ray spectroscopy. The bandgap characterization by cathodoluminescence and photoluminescence of CdSeTe as a function of Se mole fraction is one of the most comprehensive studies to date.

- Photoluminescence and cathodoluminescence showed consistent near-band-edge emission. The emission wavelength varies parabolically with Se mole fraction, consistent with literature. However, the literature attributes the band-gap bowing to the lattice transformation from cubic to hexagonal, which is clearly not the case here.
- Cathodoluminescence can be conveniently used to map composition fluctuations and to distinguish radiative and non-radiative regions on the sub-micron scale.





Scientific Personnel:
Dr. Jim Hwang

Publications, Patents, & Papers:

- E. M. Campo, T. Hierl, J. C. M. Hwang, Y. P. Chen, G. Brill, and N. K. Dhar, "Comparison of cathodoluminescence and photoluminescence of CdSeTe films grown on Si by molecular beam epitaxy," SPIE Int. Conf., Denver 2004.
- Y. P. Chen, G. Brill, E. M. Campo, T. Hierl, J.C.M. Hwang, and N. K. Dhar, "Molecular beam epitaxial growth of Cd1-xZnxSeyTe1-y on Si," J. Elect. Mat., vol. 33, no. 6, 2004.

Report of Invention:
na

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Nanoheteroepitaxial Substrates for Growth of GaN on Sapphire

Dr. Rick Vinci, Dr. Helen Chan

The overall goal of this program is to develop and demonstrate a technique for fabrication of low-cost sapphire substrates that will enable the growth of high quality GaN using MBE. The technique consists of depositing an Al thin film on a sapphire substrate, patterning the film into nano mesa structures, then converting the nano mesas to sapphire. The conversion is a two-step process of oxidation and grain growth. It is anticipated that the nano mesas will accommodate some of the misfit strain between the sapphire and the GaN leading to low dislocation density in the GaN. Patterning of an Al film into metal nano mesas with sides of 400 nm has been successful. Conversion to sapphire at 1350 °C was unsuccessful due to pattern loss, however conversion was successful at 1000 °C, as confirmed by Electron Backscatter Diffraction.

Scientific Progress and Accomplishments:

Successful fabrication of nano scale sapphire mesas has been accomplished. The fabrication process was as follows. Sapphire substrates (basal plane oriented) were coated with a thin surface layer of Al (thickness ~ 10 nm) by magnetron sputtering. The purity of the Al target was 99.99 wt.%. Next the surface was coated with photo resist, and a mask in the form of a rectangular grid was fabricated by e-beam patterning. A second Al deposition step, followed by resist lift-off resulted in an array of Al mesas on top of the Al coated substrate. (Note that the initial Al coating was found to be necessary to avoid charging effects during subsequent e-beam patterning; however this step would be unnecessary for alternate patterning techniques such as optical lithography.) The mesa dimensions were approximately 400 x 400 x 100 nm, and the pitch was ~ 600 nm.

The patterned substrates were annealed in an ambient atmosphere for 1 hr at temperatures ranging from 1000 - 1350 °C. For samples annealed at 1250 °C and above, examination by SEM and AFM revealed that extensive smoothing of the patterned features had occurred due to surface diffusion. However, the pattern of mesas was retained at the lower annealing temperatures, although some rounding took place. EBSD (electron backscatter diffraction) was used to analyze the crystal structure and orientation of the mesas. The EBSD results demonstrated that the mesas were single crystal alumina, with the same orientation as the substrate. The present approach to sapphire patterning is fundamentally different from existing techniques, as it is based on oxidation of newly introduced Al features, as opposed to removal of pre-existing material. It is therefore inherently more amenable to the fabrication of multi-layer or embedded features.

Scientific Personnel:

Dr. Richard Vinci, Dr. Helen Chan, Hyoungjoon Park

Publications, Patents, & Papers:

na

Report of Invention:

na

Technology transfer:

One specimen with a nano patterned surface was delivered to ARL.

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Flexible AM-OLED Displays on Metal Foils
Dr. Miltos Hatalis

Scientific Progress and Accomplishments:

Project addressed the advancement of flexible flat panel displays on metal foil substrates. Specifically, project demonstrated the feasibility of fabricating active matrix arrays for organic light emitting diode displays using the polysilicon thin film transistor technology on flexible metal foil substrates . Several polysilicon TFT pixel architectures suitable for 100 ppi resolution displays and different polysilicon TFT circuits for integrated display driver applications were investigated.

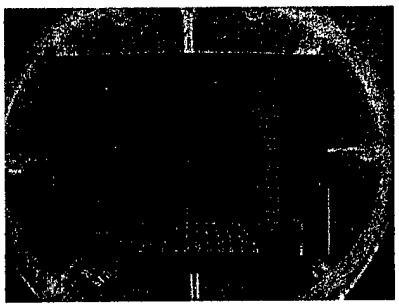
The development of the pixels architectures suitable for 100 ppi displays has been completed. The development activities for the realization of an active matrix ¼ VGA 100 ppi AMOLED display has been shifted towards a full VGA 240 ppi display which is pursued under the new contract.

Summary of Scientific Results:

- Developed polishing of flexible metal foil substrates to produce device quality surface finish.
- Developed a polysilicon TFT technology on 100 mm metal foil substrates.
- Investigated solid phase crystallization and excimer laser annealing processes for high quality polysilicon thin film material.
- Demonstrated world's highest performance polysilicon TFT transistors on 100 mm metal foil substrates with channel mobility greater than 200 cm2/Vs.
- Investigated and demonstrated functionality of TFT pixel circuits for 100 & 240 ppi displays.
- Developed voltage addressed pixel circuits with 2 TFTs and demonstrated functionality.
- Developed current addressed pixel circuits with 4 TFTs and demonstrated functionality.
- Demonstrated functionality of several polysilicon TFT circuits suitable for integrated display drivers including: shift registers, sample& hold circuits, digital to analog converters, etc.

Continuing Activities:

This project provided the ground work upon which the development of full VGA displays having 240 ppi resolution is currently being pursued under the new contract.



Scientific Personnel:
Dr. Milt Hatalis, Dr. Ray Pearson, Dr. Kamil Klier, Dr. Ivan Biaggio, Dr. Wang, Dr. Eric Forsythe

Publications, Patents, & Papers:
na
Report of Invention:
na
Technology transfer:
na

REPORT DOCUMENTATION PAGE (SF298)
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Image Fusion Research for CWD and Night Vision
Dr. Rick Blum

Scientific Progress and Accomplishments:
Project Summary:

- ANVL has great interest in IF for night vision, focus on two particular applications:

-a head mounted system (tight req. on weight, complexity and power usage)

- a vehicle mounted system (for Night Pilotage and driving, need better performance).
- Prof. Blum working on IF for different applications for about 10 year.
- Goal to apply Blum's expertise on image fusion to night vision problems.
- Towards this goal Prof. Blum's group will
  - provide an extensive survey of image fusion approaches (emphasis on NV)
  - development of an image registration tool (ANVL most immediate need – first step)
  - delivery of registered images for source images provided by ANVL
  - additive image fusion tool (give ANVL immediate utility of simple-Robust approach)
  - extension of existing fusion methods to allow Color Image Fusion
  - new algorithm development research and performance evaluation research

Project Status:

- Extensive Survey of Image Fusion Approaches (NV) → delivered
- Image Registration Tool → delivered
- Registered ANV Images → delivered
- Additive Image Fusion Tool → delivered
- Color Image Fusion → delivered
- Estimation Theory Fusion Approaches for NV
- new algorithm and performance evaluation → delivered

Scientific Results:

- Extensive Survey of Image Fusion Approaches published as book chapter

(classifies/relates existing algorithms in a common framework)

- Additive Image Fusion shown to be robust (discussed later)
- Color Image Fusion Theory documented in research paper*
- Estimation Theory Fusion Approaches documented in book chapter/paper*
- Robust Image Fusion theory documented in book chapter/paper (discussed later)

Continuing Activities:
Continue to study fusion approaches and performance

Scientific Personnel:
Dr. Rick Blum, Patti Gillespie [ARL], Philip Perconti [ANVL]

Publications, Patents, & Papers:
Book:
R. S. Blum and Z Liu, ``Multi-Sensor Image Fusion and Its Applications", (in preparation) to be published by Marcel Dekker in the special series on Signal Processing and Communications.

Book Chapter: R. S. Blum and Jinzhong Yang, ``Image Fusion using the Expectation-Maximization Algorithm and a Gaussian Mixture Model" for the book ``Advanced Video-Based Surveillance Systems", Kluwer, 2003. Editors: G.L.Foresti, C.S.Regazzoni and P.Varnshey.

Book Chapter: R. S. Blum, Zhiyun Xue, and Zhong Zhang, ``An Overview of Image Fusion", for the book `` Multi-Sensor Image Fusion and Its Applications", Marcel Dekker, 2003, Editor: R. Blum.

Book Chapter: R. S. Blum and Jinzhong Yan, ``A Statistical Signal Processing Approach to Image Fusion using Hidden Markov Models", for the book `` Multi-Sensor Image Fusion and Its Applications", Marcel Dekker, 2003, Editor: R. Blum.

Journals
R. S. Blum, ``On Image Fusion Performance Limits", submitted to Information Fusion (in revision).

R. S. Blum, ``Robust Image Fusion using a Statistical Signal Processing Approach", to appear in Information Fusion.

Conferences
Jinzhong Yang and R. S. Blum, ``Image Fusion Using the Expectation-Maximization Algorithm and the Hidden Markov Models",
VTC fall 2004.

Rick Blum, Zhiyun Xue, Zheng Liu, and David S. Forsyth, ``Multisensor Concealed Weapon Detection by Using A Multiresoltuion
Mosaic Approach, VTC fall 2004.

.Z. Xue and R. S. Blum, "Concealed Weapon Detection Using Color Image Fusion", International Conference on Information Fusion (Fusion 2003), Cairns, Australia, July 2003.

J. Yang, and R. S. Blum,`` A statistical signal processing approach to image fusion for concealed weapon detecetion", IEEE International Conference on Image Processing, Rochester, NY, pp. 513-516, Sept. 2002.

Z. Xue, R. S. Blum and Y. Li,`` Fusion of Visual and IR Images for Concealed Weapon Detection", International Conference on Information Fusion (Fusion 2002), Annapolis, Maryland, pp. 1198-1205, July 2002.

Z. Xue and R. S. Blum, "Concealed Weapon Detection Using Color Image Fusion", International Conference on Information Fusion (Fusion 2003), Cairns, Australia, July 2003.

Report of Invention:
na

Technology transfer:
na