Groundbreaking Army Research Helps Soldiers Send, Receive Information on Battlefield

Research being done at the U.S. Army Research Laboratory (ARL) is leading to significant improvements in how Soldiers send and receive data - including videos, voice transmissions, and other communications - on the battlefield.

Dr. Melanie Cole, an ARL Fellow, led a team of scientists that received award recognition for work done under their Director's Research Initiative in UV-photon irradiation. The team included Ryan Toonen, Eric Ngo, Matthew Ivill, Gary Hirsch and Clifford Hubbard from ARL's Weapons and Materials Research Directorate, and Theodore Anthony from ARL's Sensors and Electron Devices Directorate.

The DRI is an annual competition launched in 1998 that calls for high-risk, out-of-the-box research ideas expected to result in emerging or alternative technologies that significantly advance mission needs beyond conventional expectations.

The team's DRI was selected as one of the top three for 2008, and was presented at the ARL Fellows Symposium in autumn 2009. Their work has enabled technology essential to the Army's communications-on-the-move (OTM) initiative, which focuses on mobile communications platforms that connect Soldiers, sensors and weapons systems to a global grid.

The DRI research concentrated on the development of a novel materials technology solution to achieve high-Q tunable complex oxide thin film materials to enable enhanced performance, low cost, tunable Ka-band filters for the next generation communications platforms.

Cole noted that high data rate information transfer is critical to the Army's future communications needs, particularly for advanced satellite and mobile systems. She added that all communications systems require frequency-selective elements (i.e., tunable filters) to separate different parts of the received spectrum; therefore, such research to improve filter technology is critical.

Of the three classes of tunable filters, the mechanical type has low tuning speed and poor reliability, making it a poor choice for advanced communications systems, explained Cole. Both semiconductor and magnetic based materials have been extensively researched for electronic and magnetically tunable filters, respectively.

Cole added that the drawback of these devices stems from the fact that semiconductor filters and GaAs varactor diodes which are semiconductor devices in which the capacitance is sensitive to the applied voltage at the boundary of the semiconductor material and an insulator, have high losses and have low power handling capability. Magnetic materials are slow to respond to input signals, and are frequency limited.

"Improvements have been attained by developing magnetic materials with higher saturation magnetization... but these technologies are still immature and are far away from achieving the required Ka-band tunable filter performance criteria," Cole noted.

She said the commercial and military sector's drive toward developing affordable electronically tunable RF components has stimulated enormous interest in designing tunable RF devices using tunable complex oxide thin films. Although the possibility of using such thin film varactors in tunable filters has been recognized for quite some time, this application space has not been as well developed or investigated.

Research in tunable filters was greatly benefitted by support from the DRI.
Cole's group, the Integrated Electromagnetic Materials Research Team, was awarded $110,000 in seed money from DRI to investigate the development of a novel materials technology solution to achieve high-Q tunable complex oxide thin film materials to enable enhanced performance, low cost, tunable Ka-band filters for the next generation of communications platforms.

The team developed a post-growth, ultra-violet (UV) photon irradiation process science protocol to improve the materials properties of multi-component complex oxide films. Their research identified non-complex, affordable processing routes for fabricating high-Q tunable thin film oxides.

"We wanted to achieve lower dielectric loss, basically improve the Q," said Cole. The Q, or quality factor, measures the relationship between stored energy and rate of energy dissipated in certain electrical components like devices, thus indicating their efficiency. "So we looked to develop the basic science and engineering principles to improve the material which is the fundamental building block of all devices. As a result of our work, the Army's Strategic Communications Command has recognized these complex oxide thin film materials for "practical" use in communications devices.

"We needed to have a lower loss without degrading the tunability and other performance property metrics, hence we needed to create a balance of material properties," she added. "We came up with a UV-photon irradiation process science methodology to mitigate the point defects in the materials and we effectively improved the performance of the device significantly."

Cole noted that this research resulted in a dramatic materials property improvement. "We achieved an enhanced effective tunability of greater than 60 percent, which is an increase by greater than a factor of 2 over traditionally processed films, and we lowered the dielectric loss by 30 percent with respect to the current state of the art."
The result is considered a material physics break-through. "Our work resulted in a high Q as well as high tunability; that combination is unique," Cole emphasized. "We both balanced and enhanced competing materials properties, which was also unique."

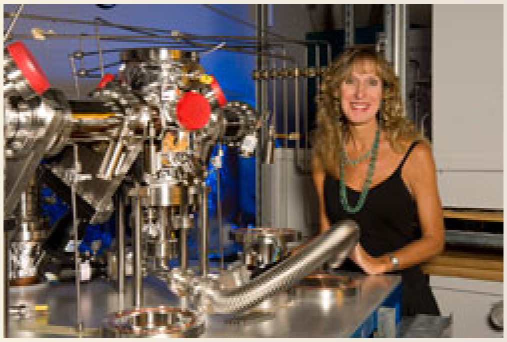
Although the team has achieved exceptional materials performance through the DRI program, its members still have more research to perform to achieve the Q values required for Ka-band tunable filters. But the performance metrics they have attained are the "best-in-class" for filter applications in the low GHz -100 MHz range. Aside from filter applications, the research should offer a much nearer time frame transition for other tunable devices whereby the balanced low loss and high tunability performance is paramount, i.e., tunable varactors at L through X band.

The team's work has since resulted in a funded research initiative for the U.S. Army Special Operations Command. This DRI technology development has enabled ARL, in collaboration with Robert Romanofsky, a senior scientist in the Antenna and Optical Systems Branch at NASA, to design and develop a novel tunable, high efficiency miniaturized antenna system (~1.75 inch diameter antenna at L-band) containing an impedance matched balun/antenna feed on a single affordable, semiconductor-industry standard wafer substrate.

ARL is scheduled to deliver a prototype of this antenna by November 2010, and the transition is expected to lead to other miniaturized, self-optimizing antenna technologies. "To our knowledge this is the smallest enhanced performance L-antenna developed to date; and this DRI research, UV-photon irradiation process science, was one of the enabling technologies that led to this to success," said Cole.

Research from this effort is also being transitioned into the Communications-Electronics Research, Development, and Engineering Center-led Army Technology Objective "Affordable Low Profile Satellite" program, which will benefit the transformational command and control system that provides and manages communications networks and services that allow Soldiers to send and receive information in order to execute their mission.

Cole stated "Our research group is grateful to have received the funds for this research via ARL's DRI program. It is an amazing program, and such a program has allowed us to perform research that we were not funded for under our current mission programs."


Dr. Melanie Cole

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