"Leading the Way in Delivering Air Force Installation Energy Assurance"

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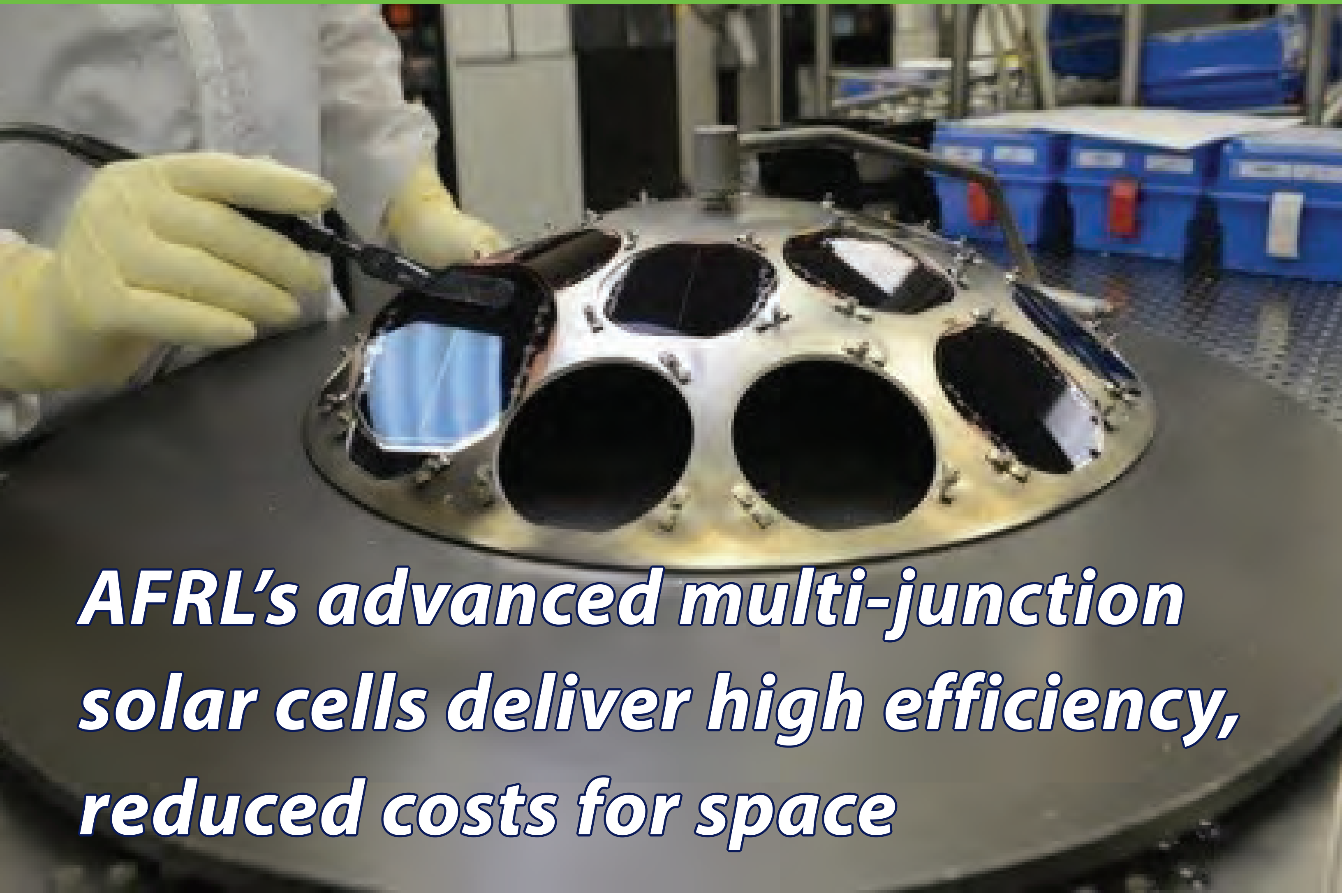

AFRL's advanced multi-junction solar cells deliver high efficiency, reduced costs for space

By Marisa Novobilski
Air Force Research Laboratory

WRIGHT-PATTERSON AIR FORCE BASE, Ohio -- Experts at the Air Force Research Laboratory continue to expand the scope of their technological expertise, rising above the Earth's surface to meet the power needs of next generation military spacecraft.

A collaborative effort between the AFRL Materials and Manufacturing and Space Vehicles Directorates, the Space Industrial Base Working Group and SolAero Technologies has resulted in state-of-the art, multi-junction solar cells destined to reduce costs and increase power efficiency for military space applications.

"These are the most advanced, efficient and affordable solar cells available for use in space," said Kerry Bennington, an electronics engineer in the AFRL Materials and Manufacturing Directorate. "These cells provide 15 percent more power than current state-of-practice solar cells of the same size. Ultimately, you can get the same

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amount of power using less cells, leaving more mass and space for other applications on a space-based platform."

As both military and civilian populations continue to rely more heavily on space-based applications for GPS, communications and more, satellites carrying these payloads require increased power to deliver additional capabilities. Maximizing power while decreasing mass and reducing cost has been an ongoing manufacturing challenge. In addition, the harsh operating conditions of the space environment, with extremes of heat and cold and high levels of radiation, require materials that can endure the volatility over long-term use.

Silicon solar cells, which are primarily used for terrestrial applications, are inexpensive when it comes to solar cell technologies, however, even the most efficient silicon-based solar panels only convert around 20 to 25 percent of sunlight to electricity. Silicon solar cells are extremely sensitive to radiation in space and experience severe efficiency degradation over time.

By contrast, modern spacecraft favor the use of multi-junction solar cells that take advantage of multiple layers of light-absorbing materials, each of which efficiently convert specific wavelength regions of the solar spectrum into energy. These cells, typically grown on germanium substrates, are more efficient than silicon and much more tolerant of radiation in the space environment. However, despite the increased output enabled by these types of cells, increasing payload power needs and limits in mass and volume of next generation spacecraft require continued development of more efficient, lighter cells of this kind.

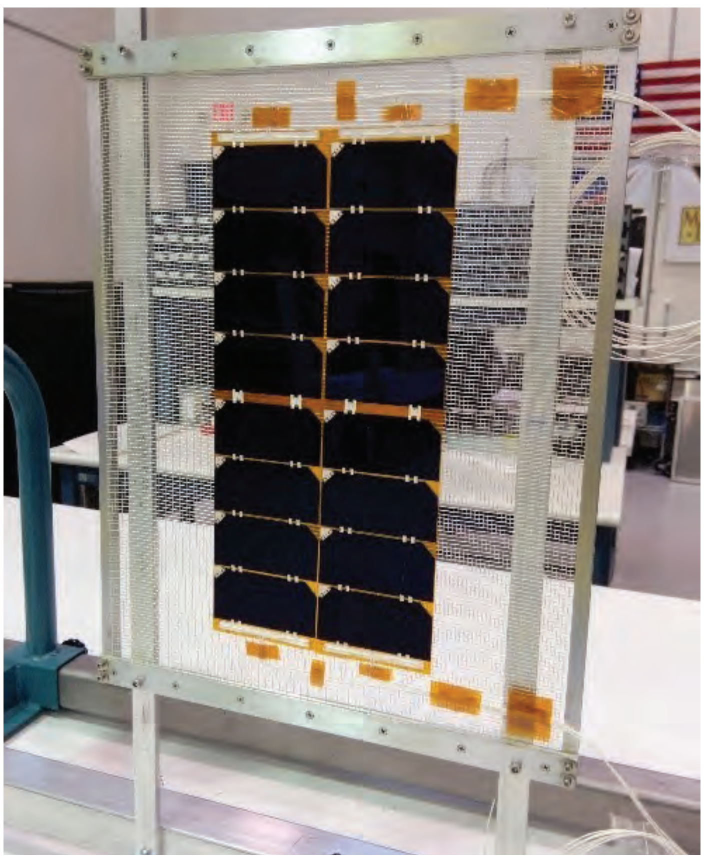
To solve the efficiency and mass needs of the space community, a collaboration between AFRL, the U.S. government and industry was launched and ultimately led to the development and refinement of a new cell architecture that takes advantage of an upside-down growth process to manufacture multi-junction cells. The process results in what are called Inverted Metamorphic Multi-Junction (IMM) solar cells, which are more efficient and a lighter weight than multi-junction cells currently in use.

"We (AFRL) began looking at this specific technology back in the mid-2000s, recognizing that increasing power needs of spacecraft would require more efficient solar technologies," said Bennington. "The challenge was to efficiently and cost-effectively grow IMM cells qualified for use in space."

The process to grow IMM solar cells begins when thin layers of semiconductor materials are deposited on a growth substrate such as gallium arsenide. The entire device is turned upside-down, and the semiconductor materials are bonded to a mechanical handle. The growth substrate, which is now on top, is removed, and processing on the front-end of the device is then completed.

"We found that by growing cells upside down on gallium arsenide, we can more effectively tailor the material properties of the individual absorbing layers. This results in more effective utilization of the solar spectrum and produces cells with significantly better performance," said Bennington. "By removing the rigid growth substrate, we end up with a cell that is lightweight and extremely flexible. A single IMM cell can convert more than 32 percent of captured sunlight into energy."

The new IMM solar cells, said Bennington, are able to achieve a 15 percent increase in power when compared with a same-sized array of standard practice multi-junction cells. This enables engineers to decrease the mass and area of a solar array and still achieve the same power, leaving more space for other applications on a space platform.



Inverted Metamorphic Multi-Junction (IMM) Solar Cells are a more efficient and lighter weight alternative to the state-of-practice multi-junction space solar cells. A collaboration between the Air Force Research Laboratory, the U.S. government and industry has led to refinement of the IMM solar cell growth process, ensuring high yield, efficient solar cell production through industrial manufacturing optimization. (Photos courtesy of SolAero Technologies)

The advanced solar cells are undergoing testing and qualification to the American Institute for Aeronautics and Astronautics S-111 standard and are expected to be space qualified this year. Recently, two CubeSats, each with 56 IMM solar cells as their only source of power, were placed on orbit, enabling these cells to gain flight heritage.

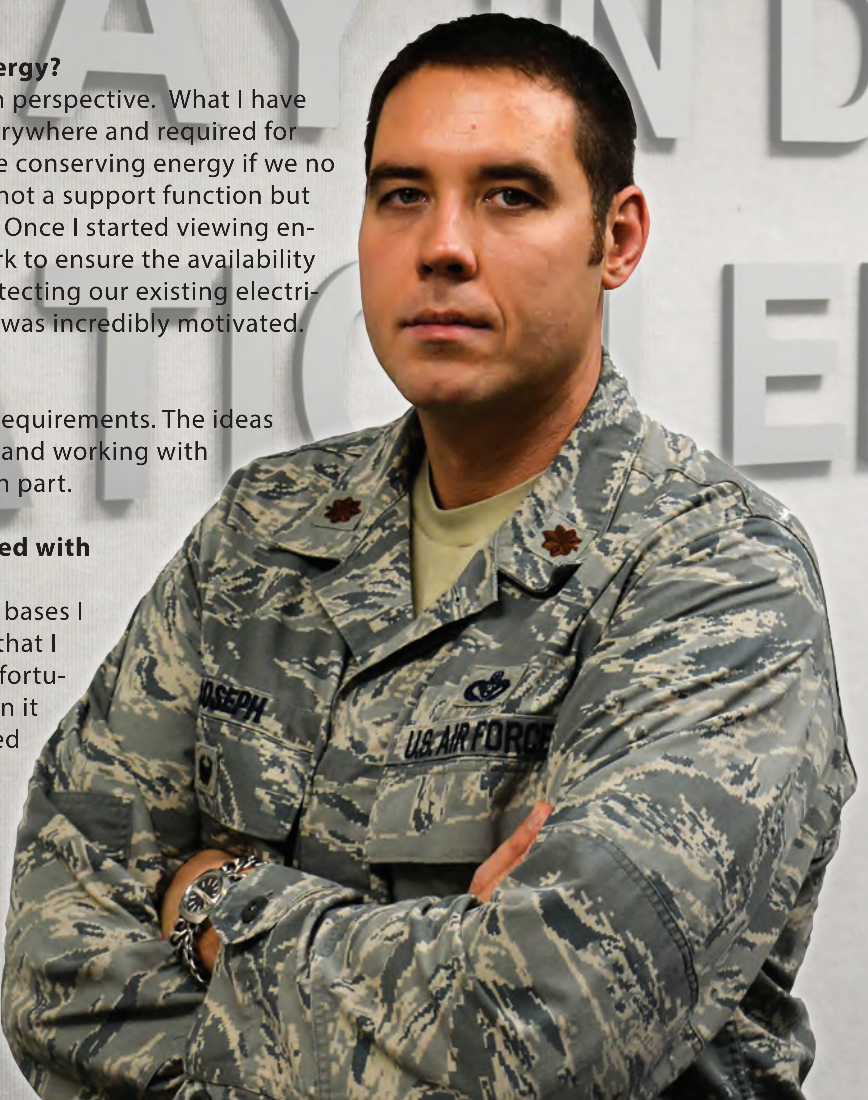
"This project shows the benefits and success of collaboration across AFRL, the Air Force, and the space industrial base. By working together, we create better technologies and ensure the American manufacturing base for the future," concluded Bennington.

Major Matthew Joseph

Chief, Strategic Energy Initiatives AFCEC, Tyndall AFB, Florida

Major Matthew Joseph is the Chief of Strategic Energy Initiatives at the Air Force Civil Engineer Center, Tyndall Air Force Base, Florida. He has a bachelor's degree in Mechanical Engineering from the United States Air Force Academy and a master's degree in Business Administration from American Military University. He has served on active duty for 15 years in locations around the world from Al Udeid Air Base, Qatar, to Tyndall Air Force Base, Florida, in a variety of engineering and command positions. During this time he has also deployed four times to locations including Iraq, Afghanistan, and Kuwait.

Please describe your role at AFCEC.
I have two main functions in my role: setting the stage for the new mission energy assurance cell and assisting with the Advanced Meter Reading System program. With the MEAC, our goal is to change the perspective that engineers use to look at requirements. The historical perspective of "one-base-one-mission/boss" is not as prevalent as it was 70 years ago when the Air Force was founded. Many of our missions are more global in nature and rely on many different bases; a matrixed mission if you will. We are trying to use technology to "look over the shoulder" of a base civil engineer to see these matrixed mission assets to ensure their missions receive the appropriate priority and level of support while giving those mission owners more visibility of risk across their domain. This doesn't take anything away from what the BCE is already doing, but hopefully frees them up to focus more on their Wing priorities. With AMRS, we are working to install advanced electrical meters to better capture electrical usage at the building level for mission critical and high usage electrical buildings across 40 Air Force bases. This enables better analytics, troubleshooting, conservation, and provides the back bone for future energy resiliency efforts.



What motivates you about working with Air Force Energy?
As a younger officer I viewed energy from a conservation perspective. What I have come to realize is far more basic than that. Energy is everywhere and required for everything; without it our missions fail. There is no sense conserving energy if we no longer have access to it. This perspective that energy is not a support function but rather a mission critical asset in its own right is exciting. Once I started viewing energy in this way and realized why we can and should work to ensure the availability of energy to our most critical assets rather than only protecting our existing electrical sources, distribution grids, and back up generation, I was incredibly motivated.

What is the most interesting part of your role?
The paradigm shift in the way we are trying to view our requirements. The ideas are sound, but finding the right way to implement them and working with the other directorates on a holistic way forward is the fun part.

Tell us a little about the relationships you've developed with the installations you work with.
It's been fun re-establishing some relationships with the bases I have been previously stationed at or working with folks that I have been stationed with before. "I'm here to help" is unfortunately something many bases don't like to hear, but when it comes from someone they already know and have worked with before, it tends to come across a little better.

What is your favorite energy-saving tip for Airmen?
If we look at our routines with a fresh eye, we could all make small changes that would likely not affect our lives, but these small changes added together can make a big difference.

‘Hot’ electrons heat up solar energy research

By Steve Koppes
Argonne National Laboratory

Solar and renewable energy is getting hot, thanks to nanoscientists — those who work with materials smaller than the width of a human hair — at the U.S. Department of Energy’s (DOE) Argonne National Laboratory who have discovered new, better and faster ways to convert energy from light into energetic electrons. Their innovative methods could provide new opportunities and greater efficiencies for solar energy conversion applications.

Argonne scientists and their collaborators created hybrid nanomaterials — measured in billionths of a meter — at the laboratory’s Center for Nanoscale Materials (CNM), a DOE Office of Science User Facility, to harness the full energy of photons.

The result was energetic, or “hot,” electrons, which carry the same amount of energy as a photon that strikes nanomaterial components. These little dynamos could eventually lead to big advances in photocatalytic water splitting — in which special materials convert solar energy into clean and renewable hydrogen fuel — and photovoltaics, which convert solar energy into electricity.

The research team focused on metals and metal nanostructures because they absorb a great deal of light, which is the first step to increasing the number of energetic electrons in an illuminated material.

“You want to preserve all that energy in the photon as much as possible, so we’re focusing on what kind of nanostructure you need in order to make a lot of those,” said Gary Wiederrecht, co-author and senior scientist and group leader of the Nanophotonics and Biofunctional Structures group at Argonne’s CNM. “In larger particles, you see very few of these energetic electrons with energies near the photon energy. So you need a smaller particle.”

The researchers simulated the material to determine the structural geometry and spectral conditions that would create the largest number of hot electrons. The winning combination: silver nanocubes and gold films separated by aluminum oxide spacers. The coupling between the silver nanocubes and gold film across the spacer layer produces a large local enhancement of the light intensity. This, in turn, allows the winning nanostructure to crank out hot electrons better than its competitors.

“One of the key advances is our ability to produce energetic electrons over a very broad spectral range — from the ultraviolet through the visible and into the near infrared,” Wiederrecht said. Processes for converting sunlight to energetic electrons typically work within smaller bands of wavelength. “That’s less useful for solar energy opportunities than if you could create hot electrons over a much broader spectral range,” he said.

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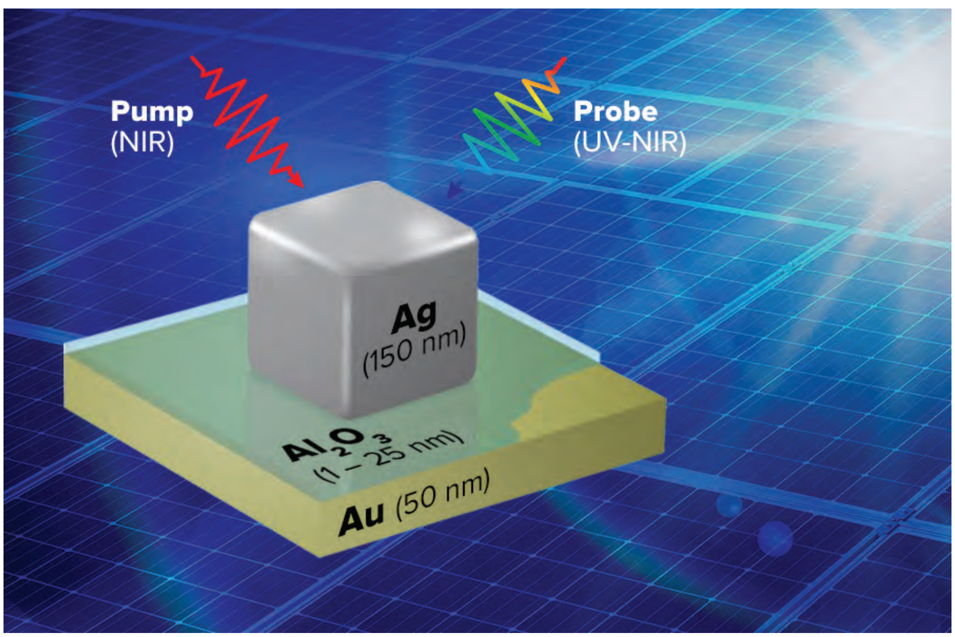

The figure in the foreground shows near-infrared and broadband light pulses (squiggly lines at top) striking a silver nanocube measuring 150 nanometers square. The near-infrared pulse excites electrons in the nanostructure, while the broadband pulse monitors their optical response. An aluminum oxide spacer separates the nanocube from a gold film with a thickness of 50 nanometers. The spacer measures between 1 and 25 nanometers thick. A water molecule, by comparison, is approximately 1.5 nanometers in diameter. (Image courtesy of Matthew Sykes, Argonne National Laboratory)

Energy directorate welcomes new AFCEC director

On behalf of AFCEC's Energy Directorate, we would like to welcome Edwin Oshiba, who was recently named the new AFCEC director. Oshiba is currently the deputy director of civil engineers, Headquarters United States Air Force, Washington, D.C.

"Mr. Oshiba will be a dynamic champion for AF energy, as we continue to lead the way for installation energy assurance," said Robert Gill, director of AFCEC's Energy Directorate.

Prior to civil service, Oshiba served on active duty in various civil engineer roles at the garrison, major command and U.S. Air Force levels. He retired in 2015 with the rank of colonel. He holds a Bachelor of Science in Electrical Engineering from Santa Clara University, California, and a Master of Science in Engineering and Environmental Management from the Air Force Institute of Technology, Wright Patterson Air Force Base, Ohio, where he was a distinguished graduate.

Read Oshiba's full bio at http://www.af.mil/About-Us/Biographies/Display/Article/565893/edwin-h-oshiba/.

'Hot' electrons *continued from pg. 4*

The team's challenge: In most metals, energy cannot transition from one level to another to create high-energy electrons.

"You need to change the direction of the electron motion or change their momentum to enable these transitions," said Matthew Sykes, a co-author and postdoctoral appointee at Argonne's CNM.

The team gathered data using a state-of-the-art instrument: the CNM's transient absorption spectrometer. With it, the team measured the rate of change in the concentration of hot electrons and determined how and when they lose energy. The data they collected could enable researchers to discover clues about how to counteract the loss or find a way to extract the hot electrons before they lose energy. The data also revealed distinct populations of hot electrons.

"We see multiple, distinct decay rates that are wavelength- and geometry-independent," Sykes said. The nanomaterial contains differing bands of energy affecting the decay rate of the hot electrons traveling within those bands. The research further revealed that the nanomaterials allow the different types of hot electrons to travel in certain directions.

"We believe these different populations of electrons exhibit different lifetimes, depending on what direction they're traveling in the material," Sykes explained. "Think of it as driving a car really fast down the freeway and you're approaching traffic. If there's light traffic, you're not going to encounter another car for some time, so you can maintain a higher speed for a longer time. In heavy traffic, you're going to have to rapidly slow down. There's different traffic depending on the direction the electrons are traveling in the metal, and this affects how long the high-energy electrons will live once they're excited."

Details of the research, which Argonne co-led along with researchers from Duke University, Ohio University and the University of Electronic Science and Technology of China, appeared in the October 17, 2017, edition of Nature Communications. The study is titled "Enhanced generation and anisotropic Coulomb scattering of hot electrons in an ultra-broadband plasmonic nanopatch metasurface."

Other Argonne co-authors from CNM include David J. Gosztola, principal technical specialist for nanoscience; Daniel Rosenmann, principal engineering specialist; and Alex B.F. Martinson, chemist in Argonne's Materials Science division.

The work at the CNM, a DOE Office of Science User Facility, was supported by the DOE Office of Science. Collaborators were also supported by the Argonne-Northwestern Solar Energy Research (ANSER) Center, an Energy Frontier Research Center also supported by DOE's Office of Science; the Air Force Office of Scientific Research Young Investigator Research Program; the Army Office of Research; the Volkswagen Foundation in Germany; and the Changjiang Chair Professorship in China.

A letter from Mark Correll, SAF/IEE

To the Air Force Energy Community,

Another year is upon us and as we look into calendar year 2018, I want to remind everyone of the vision for the Air Force Energy Program–to enhance mission assurance through energy assurance. This by no means will be a small feat, but will be made easier by extraordinary Airmen like you who support this vision and who work toward improving our energy resilience and performance every day.

Throughout the year, I will share with you what is happening at headquarters, spotlight trainings and upcoming deadlines and discuss some of the best practices from across the Air Force. Our Airmen are the backbone of the Air Force, and my hope in increasing my communication with you will only help you do your jobs to provide access to ready, reliable and resilient energy to our mission critical infrastructure and systems.

In addition to efforts like this to increase awareness, in 2018, I will also be working to finalize the management tools we need to address energy and water resilience issues and to take steps to further position the Air Force as a thought leader within DoD.

Our Airmen are shining examples of the great success we can achieve by utilizing game-changing technology, techniques, and initiatives and I look forward to a productive year, one that brings even greater energy dominance to the Air Force.

Stay up to date on all things Air Force Energy with the Energy Program online, on Facebook @AirForceEnergy, and on Twitter @AFEnergy.

Keep up the great work!

Mark Correll

Energy Express is a publication of the Air Force Civil Engineer Center, Detachment 1, Tyndall AFB, Florida.

Please send your comments, story ideas and photos to afcec.pa@us.af.mil.

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