Earlier Detection, Treatment of Diabetic Vision Complications

Data-driven imaging, improved drug delivery offer hope for quicker diagnoses, more effective therapies

Eye diseases and disorders are a serious complication for the world's estimated 400 million diabetic patients. More than 1 in 4 diabetics, for example, are believed to suffer from diabetic retinopathy (DR), a vision disorder caused when blood vessels begin growing too quickly and leak, burst or tug on the retina.

To assist treatments and interventions, Stevens biomedical engineering department chair Jennifer Kang-Mieler is developing novel techniques to diagnose DR earlier and treat it more effectively.

SHARPER IMAGING, NANOTECH MEDICINE

DR symptoms typically take six or more years to become evident, by which time the disease has usually progressed significantly. New methods that enable speedier diagnosis, particularly during early stages when the vascular changes caused by the disease are still subtle, could lead to earlier intervention and greater vision preservation.

One technique Kang-Mieler studies involves the enhancement of video fluorescein angiography (VFA) — a well-studied imaging technique relying on dye injection into ocular blood vessels — combining and processing VFA data with algorithms to detect deterioration of blood vessels during those very early, pre-clinical stages.

Her novel algorithmic system, which leverages a dynamic tracer kinetic model, has received National Institutes of Health (NIH) support of $2.5 million to date via the National Eye Institute.

"This could be a very sensitive biomarker," says Kang-Mieler, who will compare newly enhanced VFA techniques for efficacy with other standard imaging methods such as optical coherence tomography angiography and scanning laser ophthalmoscopy.

Kang-Mieler is also working to develop improved delivery of medications directly to the eye's blood vessels to treat DR.

Retinopathy's unruly growth is usually driven by the overproduction of a human growth-spurring protein, VEGF (vascular endothelial growth factor). Anti-VEGF medications have recently emerged to suppress this overgrowth, but delivering the medication precisely requires monthly injections directly into the eye, often for life.

With collaborators, Kang-Mieler has developed a therapeutic system requiring only two injections annually. Her system integrates proprietary new types of microspheres, embedded within heat-sensitive hydrogels. Mixtures of therapeutic anti-VEGF antibodies and cortosteroids, injected within a liquid, quickly become suspended in a gel once they enter the eye — allowing them to stay in place, and active, longer.

The drug delivery system, which has secured an additional $2 million in support from the NIH, has proven successful in both simulations and small-animal models. Primate research will be the next step; if achieved successfully, the team will then seek FDA approval for human trials.
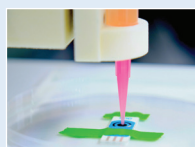
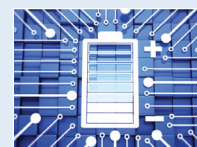Kang-Mieler's work is described in *Current Eye Research* [47(10):1-9].

INSIDE HIGHLIGHTS:

stevens.edu/research
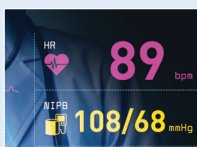
Wireless Vital Signs Advance with NASA Support

AI-Powered Bioprinting of Organs, Skin

Charging Toward Stronger, Safer Batteries

STEVENS QUANTUM TECH VENTURE APPEARS WITH QCI ON NASDAQ STAGE

A Stevens quantum technology venture acquired by a Nasdaq-listed software firm was represented on the exchange's New York City stage during a closing-bell ceremony.

Researcher Yuping Huang's Stevens-based photonics venture QPhoton was acquired in spring of 2022 by Virginia-based Quantum Computing Inc. (QCI). Huang will remain with QCI as a director and Chief Quantum Officer, with QPhoton operating as a wholly owned subsidiary.

The companies are working to jointly develop, market and sell quantum and photonic products, solutions and services including ready-to-run, full-stack quantum systems.

"As a quantum innovator, QPhoton leverages two decades of leading quantum studies to bring significant quantum value to the market," noted Robert Liscouski, CEO of QCI.

Since 2014, Huang has developed quantum technologies at Stevens with support from the U.S. Department of Defense, the National Science Foundation, the U.S. Department of Energy and NASA. His research focuses on room-temperature-practical quantum and photonic hardware capable of quantum computing, networking, communication, imaging, sensing, processing and security.

Virginia-based QCI is focused on quantum-optimization software and algorithms for newly developing quantum computing platforms, with an eye toward applications in logistics, supply chains and other big-data challenges.

Exploring a 'Magic Twist' to Boost Graphene

Unique manipulations create superior wearable materials

Stevens nanotechnology researcher Annie Xian Zhang has received National Science Foundation (NSF) CAREER award support to pursue materials that could make wearable sensors thinner, more flexible and better-performing.

Zhang will investigate the curious thermal interactions and properties that result when sheets of ultra-thin graphene are formed into moiré patterns, a geometrical design created when one hexagonal pattern is superimposed upon another, then twisted.

Twisted at an angle of exactly 1.1 degrees — known as the "magic angle" — single atom-thick graphene crystals suddenly change properties, even becoming superconductive.

Zhang will use a miniaturized robotic arm in her Stevens lab to precisely manipulate and rotate layers of graphene atop each other across a spectrum of moiré patterns, each with unique thermal properties that she will then characterize.

The work could have broad applications in beyond-silicon electronics, sensors and superconducting thermal switches, including improvements in heat dissipation — a current bottleneck in wearable-device development.

The NSF-supported project, "Investigation of Thermal Transport in Moiré Pattern Structured Materials to Push the Extremes of Thermal Modulation," will run through 2027.
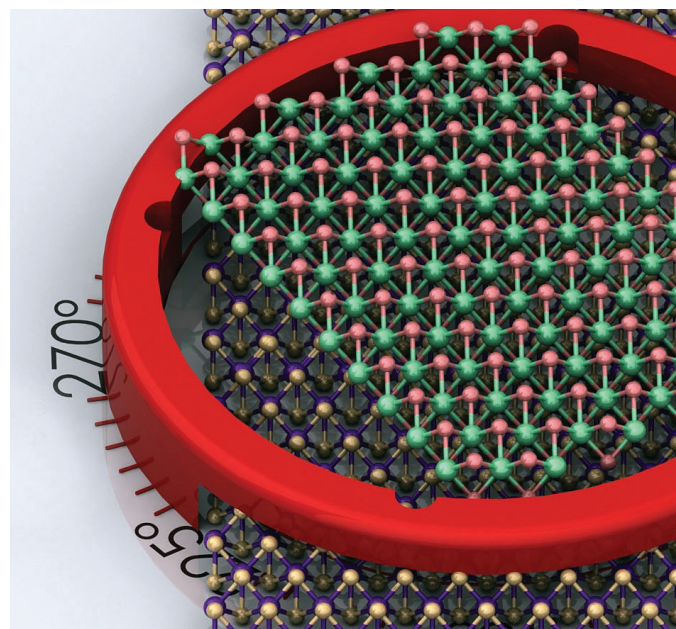
A New Strategic Plan, Further Enhancing Stevens Research

As we progress through the fall semester, I have two important pieces of Stevens news to share.

First, I will be stepping aside from the role of Vice Provost for Research and Innovation in mid-November. Ed Synakowski will join Stevens as VPRI at that time and continue leading our remarkable progress. I will return to teaching and research as a Stevens professor of chemical engineering and materials science and as Director of the Highly Filled Materials Institute.

Second, in June the Stevens community created, delivered and secured approval of a new 10-year strategic plan, *Stevens 2032: Inspired by Humanity, Powered by Technology*. This road map will guide the next decade of the university's progress as we continue to grow in size, impact and national profile.

Stevens' research enterprise is a significant part of these plans. You may know that, since 2011, our sponsored research support has grown by a remarkable 135%. In other words, the university has more than doubled its research awards during a period when traditional support resources for academic research have not been expanding.

This is wonderful news and speaks well to the quality research Stevens' talented faculty are producing.

Our new strategic plan calls for the continued ramping up of sponsored research application and award activity, but also — importantly — of the licensing, patenting, commercialization and other intellectual property activities that are critical to bringing new technologies to market and to forging new partnerships with industry leaders.

We also plan to create a number of new interdisciplinary research centers over the next decade, fortifying our efforts in key technological areas that benefit society such as healthcare, fintech, quantum science and resiliency. These new centers will rely on the close collaboration of our faculty and will work closely with government agencies and fellow institutions of higher learning to continue producing important research.

Please enjoy reading this issue of *IMPACT* and continue to follow the latest developments in our research program as we move forward exploring and producing exciting new discoveries in engineering, materials, medicine, finance, climate science and many other key domains.

Wishing you all a healthy and productive fall semester and holiday break.

All my best,

Dilhan M. Kalyon
Vice Provost for Research and Innovation

Bioprinting Organs, Skin Moves Closer to Reality

Team advances microfluidics technique with computational boost

Human organ transplants offer a crucial lifeline to those with serious illnesses, but there remains a deficit of healthy organs for transplant. In the U.S. alone, more than 100,000 patients wait for organs at any one time.

Stevens researcher Robert Chang, working with a team of student and faculty researchers, is developing technologies to 3D-print human organs of any tissue type.

SMALLEST-EVER SCALES, AIDED BY AI
Printing organs using bio-inks (hydrogels laden with cultured cells) requires extremely fine control over the geometry and size of printed microfibers that existing 3D printers cannot obtain. Chang and his team are developing a microfluidics process, powered by novel algorithms, that precisely manipulates liquids through tiny channels at a far smaller scale than previously possible.

A microfluidics-based printer, he says, could potentially print biological objects on the order of tens of micrometers — approximately the size of a single body cell.

The new techniques also bring the ability to combine multiple biological materials within a single printed structure. That's important, notes Chang, because complex organs such as the liver and kidney require many different cell types, precisely combined.

"Being able to operate at this scale, while precisely mixing bio-inks, makes it possible for us to reproduce any tissue type," he explains.

Chang's team will next explore 3D printing to create skin and other tissues, potentially opening the door to enabling replacement tissues printed directly onto patients' wounds in real time. Stevens doctoral candidate Ahmadreza Zaei also contributed to the research, detailed in *Scientific Reports* [Vol. 12: 1-16].
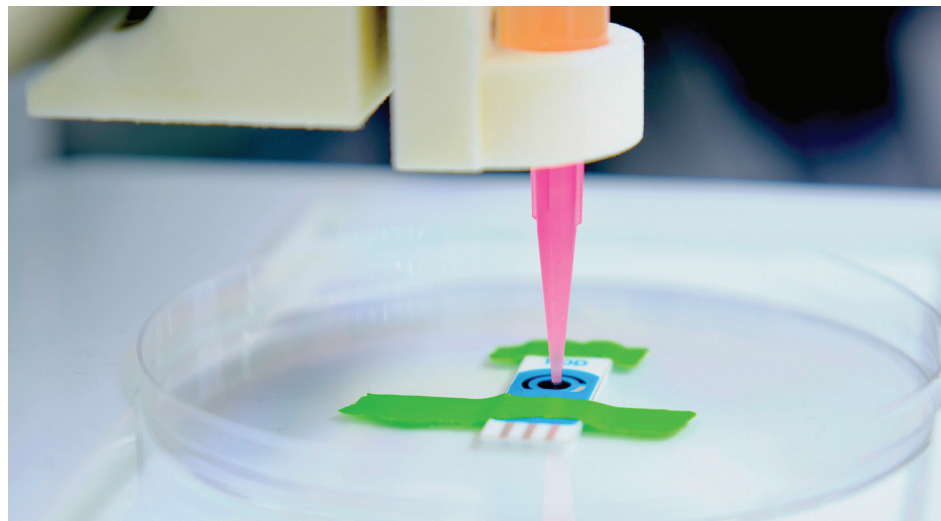
NASA Funds Ice-Mapping AI to Monitor NYC Water

Stevens-developed image processing techniques will aid reservoir, watershed management

New York City's municipal water supply system, one of the largest on the planet, delivers more than 1 billion gallons of drinking water daily — all drawn and transported from a series of watersheds and reservoirs in upstate New York.

Monitoring and managing flow throughout these watersheds and this delivery system is a continual challenge.

To assist, Stevens professor Marouane Temimi has received a $400,000 NASA award to build an algorithmic tool that will help enable fine-tuning of the system's supply by inspecting river and lake ice imaged by NASA satellites overhead.

ICE COVER AND MELT: KEYS TO WATER SUPPLY

Dynamic forces including climate change, population growth and movement, and alterations in land-use all complicate the water-supply picture.

In cold regions such as the U.S. Northeast, for instance, winter interactions between ice and river and stream flow significantly influence supply management. Accumulating river ice can slow and block the normal flow of water. Or, depending upon ambient temperature, the shape and depth of a river, ice thickness and other variables, river water can also break up and melt river ice packs gently, improving overall flow and water supply.

Temimi's starting point will be his own laboratory's existing river-ice mapping tool. The newly developed model will be built on top of that interface, processing winter satellite images of Northeastern U.S. and Canadian lakes and rivers in real time and inferring ice cover — then using that information to estimate watersheds' various river flows beneath the ice cover.

Government agencies will leverage the tool when it is eventually deployed, notes Temimi. The National Oceanic and Atmospheric Association's (NOAA) National Weather Service Northeast River Forecast Center will use the new interface to help track river ice data to inform precipitation and flood forecasting, while the New York City Department of Environmental Protection (DEP) — which manages the city's water supply — will use the system to monitor inflow to its reservoirs and adjust flows accordingly.

NASA's support for Stevens' work on the project, titled "Synergistic Use of Multi-satellite River Ice Remote Sensing and Hydraulic Modeling to Enhance Operational Streamflow Forecast in Northern Watersheds," will continue through spring 2025.

STUDY: NFT BUZZ QUICKLY WEARS OFF

Stevens cognitive research demonstrates how digital collectibles may quickly lose luster

Non-fungible tokens (NFTs) have taken the fintech world by storm. But how intelligent, profitable and sustainable is an investment in these unique products?

New Stevens cognitive research suggests the buzz around NFTs often quickly fades — a victim of their own success.

A team led by Jordan Suchow, a professor in the Stevens School of Business, conducted the first known cognitive study of NFT trading, examining the popular Bored Ape Yacht Club set of 10,000 digital images. Some of these images possess common traits, while others have completely unique aspects.

When NFTs first began trading, images with very rare features were highly sought-after. However, their uniqueness pushed the rarest types of images into public discussion, dissemination and visibility. To learn whether greater visibility affected their value, Suchow's team identified both the rarest and most common aspects of the Bored Ape NFTs, then tracked their changing value over time.

While uniqueness strongly correlated with higher value in early trading, the team found, that connection all but disappeared as newcomers began trading those same NFTs.

"We've revealed a general principle: that demand for rarity is self-defeating," Suchow notes.

He adds, however, that the study found some features (such as unusually colored backgrounds) *did* retain their value over time even as other rare aspects of the NFT images lost value.

The work was presented at the 2022 Cognitive Science Society Conference (CogSci) in Toronto in July.

NEWS & NOTES

Stevens named **Ed Synakowski** as Vice Provost for Research and Innovation, effective November 16, 2022. Synakowski, an award-winning physicist, previously served in leadership roles at the **U.S. Department of Energy**, the **University of Wyoming** and the **University of Nevada, Las Vegas**.

The U.S. Department of Defense (DoD) awarded $2.9 million in renewed support to **Christos Christodoulatos** and Stevens faculty collaborators to continue developing net-zero carbon strategies, technologies and systems.

Abhishek Sharma and Lucia Wang Ph.D. '22 authored "SERDs: A Case Study in Targeted Protein Degradation," a summary of recent advances in the development of estrogen receptor-targeting breast cancer therapies, in *Chemical Society Reviews*.

Jason Rabinovitch presented "Modeling Supersonic Parachute Inflations for Mars Spacecraft" with co-authors from **Stanford**

University and **Caltech's Jet Propulsion Laboratory** at the 2022 Aerodynamic Decelerator Systems Technology Conference in Toulouse, France. He also co-authored "A Fast and Robust Surface Sample Acquisition System for a Venus Lander" in *Planetary and Space Science* [Vol. 215, 105473].

Yanghyo "Rod" Kim received approximately $1 million in support from the DoD to develop novel systems and technologies to wirelessly connect components in future space missions.

Svetlana Malinovskaya received support from the **Office of Naval Research** for her project, "Broad Frequency Range Chemical and Biochemical Material Remote Detection Using Quantum-Enhanced FAST CARS." The research will work toward techniques for early detection of hazardous chemicals in the air, using femtosecond laser pulses.

Jon Miller received support from the **U.S. Army's** Coastal Research Program for his project "Evaluating the Influence of Water Level on Wave Attenuation of Natural and Nature Based Features in Low-High Energy

Environments," an effort to combat sea level rise-induced erosion.

Samantha Kleinberg and doctoral candidate **Louis Gomez** co-authored "Classification of Level of Consciousness in a Neurological ICU Using Physiological Data" in *Neurocritical Care* with collaborators from Columbia University.

Damiano Zanotto and **Kishore Pochiraju** were awarded nearly $1.2 million by the DoD to advance work in AI-powered lower-limb orthotics to assist exercise therapy. The researchers will collaborate with the Kessler Foundation on the project, "Machine Learning Methods to Individualize Powered Orthotic Intervention for Improved Functional Recovery after Lower Extremity Trauma."

Mo Mansouri delivered a keynote speech at the **International Conference on Systems (ICONS) 2022** in Barcelona.

Charging Toward Stronger, Safer Batteries

When it comes to the batteries that power our laptops, smartphones and electric vehicles, Stevens materials scientist Jae Chul Kim is thinking outside the box.

And if his ideas pan out, next-generation batteries could last up to 30% longer, become thinner (opening the door to life-saving biomedical uses) and be far less likely to catch fire.

NOVEL MATERIALS, MOLECULAR ARRANGEMENTS
Kim's work involves investigations into solid-state lithium batteries, which last longer and are far safer than the liquid electrolyte-based lithium-ion batteries powering most devices and EVs.

There are significant challenges in designing and making solid-state batteries, particularly at the interfaces where their components — cathodes, anodes, electrolyte materials — touch. Interfaces can physically fracture after repetitive discharge and recharge; chemically oxidize, at lithium batteries' relatively high voltage; or become diffuse, as different elements combine and react.

"These problems are combined; you cannot separate them," notes Kim. "To make a better battery, you have to solve all of them at the same time."

A promising new class of battery substances known as superionic conductors — solid electrolyte materials that retain high conductivity, comparable to that of a liquid electrolyte, as lithium ions fly around within it — has recently emerged.

That's where thinking outside of the box comes in.

Most current or developing battery designs involve well-studied arrangements of atoms or groups of atoms. Kim explores non-crystalline materials with novel molecular arrangements that retain the desirable properties of their crystalline forebears.

The successful development of improved solid-state batteries could also usher in new classes of medical uses, such as pacemaker batteries, Kim says.

"You could make solid-state lithium batteries very thin, even into flexible films, which is something you can't do with current lithium-ion technology," he points out.

Kim's research is supported by the U.S. Department of Energy, energy group PSEG and battery manufacturer LG Energy Solution.

INNOVATION APPLIED

Wireless Vital Signs, Using Radar and AI

NASA-supported technology touchlessly monitors heartbeat and breathing

Astronauts, athletes, hospital patients and others require constant monitoring of vital signs to watch for indications of dangerous health problems. That means strapping sensors directly to the chest, wrist or abdomen — an uncomfortable, restrictive solution.

Stevens professor Negar Tavassolian, working with doctoral candidate Arash Shokouhmand and a New Jersey health technology firm, has developed a wireless system to monitor vitals — and NASA has agreed to support its development.

HIGH ACCURACY IN EARLY TESTS

The proposed system integrates scanning data and 3D color camera images to produce accurate vital signs, individually identified, in real time.

A continuous-wave radar scans the body while also imaging it in 3D with a color/depth camera. The system identifies landmarks on the human torso, using a type of AI known as a convolutional neural network, constantly correcting the focusing radar beam to obtain the best possible estimations of heart and respiratory rate.

After imaging changes in those body regions, additional methods calculate the likely respiratory rate and heart rate in real time.

To simulate spacecraft crew conditions, Tavassolian's group has tested the technology with individual subjects as well as groups of multiple subjects doing simulated tasks, in different poses and at various angles and distances, as radar beams scanned and imaged them.

During early testing, respiratory rates of the subjects were accurately estimated more than 96% of the time for most cases while heart rates were accurately estimated more than 85% of the time in every test scenario.

After tweaking the software to focus more specifically on upper chest and abdomen regions, accuracy improved even further.

One key to the system's broader potential: It can personalize measurements. Radar systems alone can't yet recognize individuals in data streams, but the integration of a camera system, AI and facial recognition allows this new system to know which individual in a group has, for example, suddenly experienced a racing heart or stopped breathing.

The technology firm Autonomous Healthcare collaborated in the research, which was reported in *IEEE Sensors Journal* [Vol. 22, 12].

"Stevens has been the perfect academic partner for us," notes Autonomous Healthcare CEO and co-founder Behnood Golami.