Yale University Innovation Pipeline 2020

Technologies for Partnering

Office of Cooperative Research
ocr.yale.edu
WHAT WE DO

• Identify and foster innovative technologies with significant market potential

• Help Yale researchers navigate the patent process

• Connect Yale researchers with academic and industry partners

• Introduce startups to funding sources

• Build startup management teams

• Provide commercialization workshops & skill-building to the research community
Physical Sciences
Higher Efficiency GaN Laser Diode (LD)

The key factors preventing the widespread use of LD lasers in lighting are:
- Insufficient Power Conversion Efficiency (PCE)
- Aluminium degrades performance and lifetime.

- NP GaN offers 2X higher electrical efficiency (PCE) than commercial State Of The Art LDs.
- Brings LD PCE in line with commercial LEDs.
- NP GaN is Aluminum-free.
- Lowers the minimum current density for emission.
- Allows higher blue/green laser power output (Boosts Optical Field X3).

About Nano Porous (NP) GaN:
- A novel electrochemical etching process alters the optical index of GaN by making it nanoporous.
- This is a commercially viable process that can be implemented in any LD or LED chip facility.

Yale Patent Status:

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High Power automotive and lighting applications
Removal of Particulate Contamination by Microfibrils

Existing dry dust decontamination techniques are limited to +10micron particles. Smaller particles can only be removed by techniques that are partially destructive to the substrate and involve cumbersome batch processing treatments. As a result Quality Assurance in cleanrooms and other critical environments is time consuming and affects product yield.

Microfibril technology is a zero-adhesion contact surface that collects impurities and contaminant particles with no damage to substrate features.

- Nondestructive over a full range of surface topologies
- May be designed to a specific cutoff Particle Size Distribution
- Removes 10micron to 100nm particles
- Uptake 10-20 monolayers per surface area.
- Compatible with any surface or contaminant.
- Water or electrostatic cleanable
- Injection molded PDMS roller prototype.

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**Genotype independent hybrid cereals**

The Silkless gene *Sk1* is a maize sex determination gene, the first single gain-of-function gene known to control survival of functional pistils. It enables production of unisexual flowers (either staminate or pistillate on separate plants) in cereal crops.

- Lower cost of development for hybrid seed through outcrossing of unisexual plants. Only one generation of gene-editing per inbred, instead of 6-8.
- More efficient production of hybrid seed through wind pollination of unisexual flowers.
- Profound implications for food security increasing crop yields by 20-40% without placing additional land under production.
- Better abiotic stress resistance and disease resistance.
- Limited only by resources vs. current hybrid sterility systems which are genotype and environment-dependent.

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Stable Black Phosphorous epi-wafer

Black Phosphorous 2D thin films promise to surpass Graphene as the most favorable materials for future nano- and opto-electronics thin film solar, photo-detectors, and logical devices.

Current synthesis routes, exfoliation and plasma, face major challenges i) volume, ii) stability and iii) uniformity. Yale inventors have found a way to make high quality wafer-scale deposition possible with no device degradation in air.

Proof of Demonstration:
- Boron Nitride/Black Phosphorous heterostructures
- Suits epiwafer and flexible substrate production.
- Uniformity is sufficient for thin-film transistors.
- Atomic layer control allows fine bandgap tuning.
- A novel thin-film BN insulator prevents degradation.

Status:
- Composition and method Patent; Seeking fabrication partner for high pressure/ temperature reactor collaboration.

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Next Generation High Speed Thermal Sensor

- There are two types of thermal infrared cameras in use today. Low cost uncooled microbolometer-based cameras (Vanadium Oxide or Amorphous Silicon) which have a slow time response and are limited to around 30 frames per second (30Hz).
- Cooled photon-counting cameras that can measure fast transients (MBE grown superlattices, but they are very expensive and need cooling to low temperatures).
- OCR 7572 nano-bolometer is operational at room temperature, high resolution (16 times better) and Megahertz response time which makes a host of applications possible from Advanced Driver Assistance Systems (ADAS) to Machine vision cameras for component testing and thermography.
- It uses a well-established material system Ultrathin Silicon-On-Thermal-Insulator (SOTI)
  - Demo 2 × 2 Bolometer array of operational wavelength range of 8 - 12 μm with pixel dimension of 8 × 8 μm²
  - Large integrated bolometer arrays possible with an individual pixel size of 6 × 6 μm² and NETD below 50 mK.

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1 Nm NanoFiltration Membrane

- A self-assembled Liquid Crystal (LC) monomer film.
- Simple liquid phase roll-to-roll fabrication.
- NanoFilters now have both high permeability and narrow pore size distribution. 
  - 0.9 – 1.1 nm ‘cut-off’
- Tortuosity ~ zero.
  - aligned vertical orientation
- Pending patent applications.

Excellent membrane assembly device candidate:
- Performance flux tested with mechanical support layer for durability.
- Free standing/mounted on microporous mechanical supports (25mm diameter).
- Compatible with EU food and beverage compatibility requirement.
- The global market potential for <10nm filtration without requiring PTFE is about $40MM, and growing.
- 1 Nm cutoff is required in high cost microelectronics filtration, gas separation and sensor markets.

Fig. (a) – (e) Manufacturing by soft confinement is based on the self-assembly of discotic or lyotropic small molecule mesophases.

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Neuroprobe sensor

- NeuroProbe is a brain implantable device for multimodal brain monitoring in the Neuro-ICU.
- Makes early detection of secondary brain injury post TBI possible, which, if detected early, may be reversible.
- The integration of sensors on a single probe co-locates data acquisition, a dramatic improvement for research, beyond patient benefit.
- Portable multimodal interface device NeuroLink stores and relays the digital data to standard clinical monitors or a portable monitor.
- Placement possible at bedside or at a military field facility.

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Fig 1. Intracranial pressure (icP), intracranial EEG (icEEG), intracranial temperature (icT), brain tissue oxygen (PBTO2) and cerebral blood flow (CBF)
PremieBreathe HHFNC system

Portable Compact High Flow Nasal Cannula (HHFNC) Therapy for Neonates and Infants

- Affordable, breathing aid to support newborns suffering from respiratory distress in resource-limited facilities.
- PremieBreathe avoids complications that result from conventional bCPAP nasal cannula and dry cold high pressure, such as nasal trauma including granulation, ulceration of the nostrils, and distended abdomen which can lead to malnutrition.
- UV water sterilization mechanism eliminates bacterial contamination.
- Mobile unit replicates the outputs of commercial immobile devices for approximately 1/10 of the cost, or $500.

Fig 1. 2018 fully-functional HHFNC system prototype with consistent bench level functionality and desired airflow rate of 0-10 L/min, temperature of 32 degrees Celsius and relative humidity of 90-95%.

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Performance coating for electrowinning

Paint-on anti-corrosion layer reduces power costs and extends the useful life of electroplating anodes.

“Blue Solution” is a self-assembling monolayer of Iridium Oxide that preserves the clean wetted-area of the anode and mitigates soluble lead formation.

- Dip coat application, self-assembles - no electrodeposition.
- 6% reduction in power costs.
- Several fold increase in useful life of the permanent anode.
- Reduce soluble lead in waste water.
- Prevents buildup of sulfate/chromate layers and flaking.
- Synthesis cost $0.75/m².
- Stable under field conditions (tolerates organics, binders).

Example electrowinning applications: Zinc (lead/silver alloy), Nickel (lead), Copper (lead/antimony)

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PEGylated Amnion scaffold for use in wound management

A wound repair hydrogel that combines the benefits of amnion ‘scarless healing’ with a hydrogel scaffold that conforms to the wound. Advantages compared with amnion sheet:

- Significantly less wound contraction.
- 2 x faster surface closure.
- Lower infection risk (animal data).
- 8 times less amnion used.
- Utilizes FDA approved materials.
- Conforms to the wound and provides greater shear strength in healing.

Can be applied as a gel and cured in white light,
or as a prefab dressing providing a much longer shelf-life than amnion sheets.

Applications: diabetic foot ulcers; corneal repair; burn wounds. The mechanical properties of the hydrogel (mechanical stiffness of the scaffold, individual pore size and porosity) can be tuned through a crystal templating method developed at Yale.

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Biomimetic Lymph node

Advances a Non-Engineered approach to adoptive cell therapy (tailored multi-targeting of antigen-specific immune/regulatory signals).

- All-in-one expansion and activation reduces contamination risk, eliminates operator and open handling of material.
- Single-use disposable cartridges permits bedside incubation.
- Current Car-T products in clinical trials require separate offsite cell manipulation steps (eg. Dynabeads™, GE Wave™).
- Paracrine delivery of IL-2 lowers T cell exhaustion.
- Ex-vivo ‘lymph node’ structure consists of a heterogeneous nanoparticle substrate (CNP):
  - T-cells are expanded **10x faster** and are **3x more potent** than current methods for T-cell expansion
  - The percentage of T-cells **activated** by CNP is above 90% in the first week – **top figure**
  - Continuously better at T-cell expansion than other methods **in vivo** – **bottom figure**
  - Uses 1 ng of reagents for 1 million cells
  - Uses 1000x less of T-cell growth factor IL-2

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**US Patents 9,737,593; 8,629,098**  
‘Compositions and methods for adoptive and active immunotherapy’
Unipolar CMOS solves the mobility mismatch between NMOS and PMOS by utilizing two n-channels:

- 20x higher electron mobility
- reduced overall channel width
- cheaper fabrication cost (due to fewer masks and fewer fab steps)
- lower power

Two key commercial focus areas:

1. Low-Power, Short-Range IoT Networks

2. Low-Power, Wide-Area Networks

Why is Wi-Fi Power Consuming?

- Wi-Fi transmitter consumes 500 - 700 mW
- 10,000X Less Power (than WiFi)

Passive Wi-Fi

- Generate Wi-Fi packets using reflections
- 1, 2, 5.5 and 11 Mbps Wi-Fi @ 15-60 μW

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RF MEMS Filter for high-speed data processing

NIBS (Nonlocal Inter-band Brillouin Scattering) is a Tunable Narrowband Microwave Filter that overcomes traditional MEMS filter challenges of limited tunability and resolution.

- Single-sideband NIBS filter allows for tunability from 0.1->100 GHz
- Narrow bandwidths ~10 MHz
- High spur-free and linear dynamic range
- Potential for complete integration

The global MEMS market is projected to grow to $25 billion in 2022, driven largely by growth in RF applications like RF MEMS filters.

US Patents:
- Acousto-optic coupling techniques US20200030849
- Brouillon Laser US20180331490
- Optoacoustic signal processing US20200050030

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Electrochemical production of H2O2 from water

- Membrane-less stack, no electrolyte (conventional H2O2 devices require electrolytes).
- Disinfection applications 1) H2O2 accumulation in water, or 2) H2O2 vapor in textiles.
- ALD process and novel oxide films permit compact lamination which is required for efficient H2O2 production, other catalysts cannot achieve this.

Outperforming competitors 20mM H2O2 at >90% Faradaic Efficiency Fig. (a) above.
Stable current-voltage behavior in single-layer (Ti,Mn)Ox and bi-layer (W,Mn)Ox+(Ti,Mn)Ox coatings Fig (b) above.

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HALO realizes a general-purpose architecture.

- Novel interconnect and switch processing elements developed in Manohar lab.
- HALO achieves 4-57× reductions in power consumption versus known software alternatives.
- All processing pipelines operate under 15mW budgets with greatly reduced radio RF bandwidth.
- Evaluation suits full range of neurological disease domains: from neuronal signal extraction to seizure onset detection (epilepsy) and movement intention (paralysis and Parkinson’s disease).
- The HALO team is currently (2020) taping out the first generation of HALO chips.
**III-V semiconductor integration with GaN**

An epitaxial growth method to deposit III–V material Gallium Nitride (GaN) on an Si or silicon-on-insulator (SOI) wafer, or any amorphous template.

- More versatile version of the conventional Template-Assisted Selective Epitaxy (TASE), but designed specifically for GaN.
- Results in high material quality and is compatible with CMOS processes.
- System fabrication costs may be significantly lower than discrete chip packaging approaches.
- **No material defects** due to crystal lattice mismatch with Si.

Method: (1) deposition of a textured aluminum nitride seed on SiO2, (2) resulting longitudinal growth of gallium nitride single crystals.

Bandgap versus lattice constant of semiconductors of technological relevance. The greater the difference in lattice constant between two materials, the more challenging their co-integration.

TASE (above) borrows its seed region from a single-crystalline substrate, this is prohibitive for GaN.

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DRAGONFLY™ array digitally fuses many images from smaller telescopes together.

- **Low surface brightness imaging:** DRAGONFLY™ is equivalent to a 1 meter aperture refractor (the largest in the world) and it operates at an ultra-fast f/0.39 focal ratio with an enormous (6 square degree) field of view and optical scattering an order of magnitude lower than conventional telescopes.

- **Low cubesat payload:** The segmented nature makes it extremely scalable.

- **Potent wide-area imaging spectrometer:** DRAGONFLY™ employs a tilting narrowband interference filter which means it can isolate the glow from the nearly invisible (to every other telescope) at a specific wavelength. Array can be tuned to the wavelength of interest. This is not possible with conventional, unsegmented telescopes.

**Applications:** 3D spatial information for astronomy; searches for weak emissions from dark sites at specific wavelengths; Geospatial surveillance and remote sensing.

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Peripheral Arterial Disease (PAD) is a major Public Health Crisis:
PAD Patients > 200 million worldwide
Majority are over age 65 (double by 2040)
~900,000 PAD procedures per year
~ 57% are reinterventions

Current Practice for all PAD procedures (diagnostic and interventional) is unidirectional ONLY (Medtronic, Cordis, Terumo, Cook, Merit).

DeTour Sheath allows bi-directional diagnosis and intervention in the same procedure:
- Overall cost savings for hospitals and outpatient centers (~$250 million per year)
- ↓ Total number of interventions & use of closure devices
- ↓ Access site complications by 50%
- Projected Sheath Cost per unit → (~ $150)

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