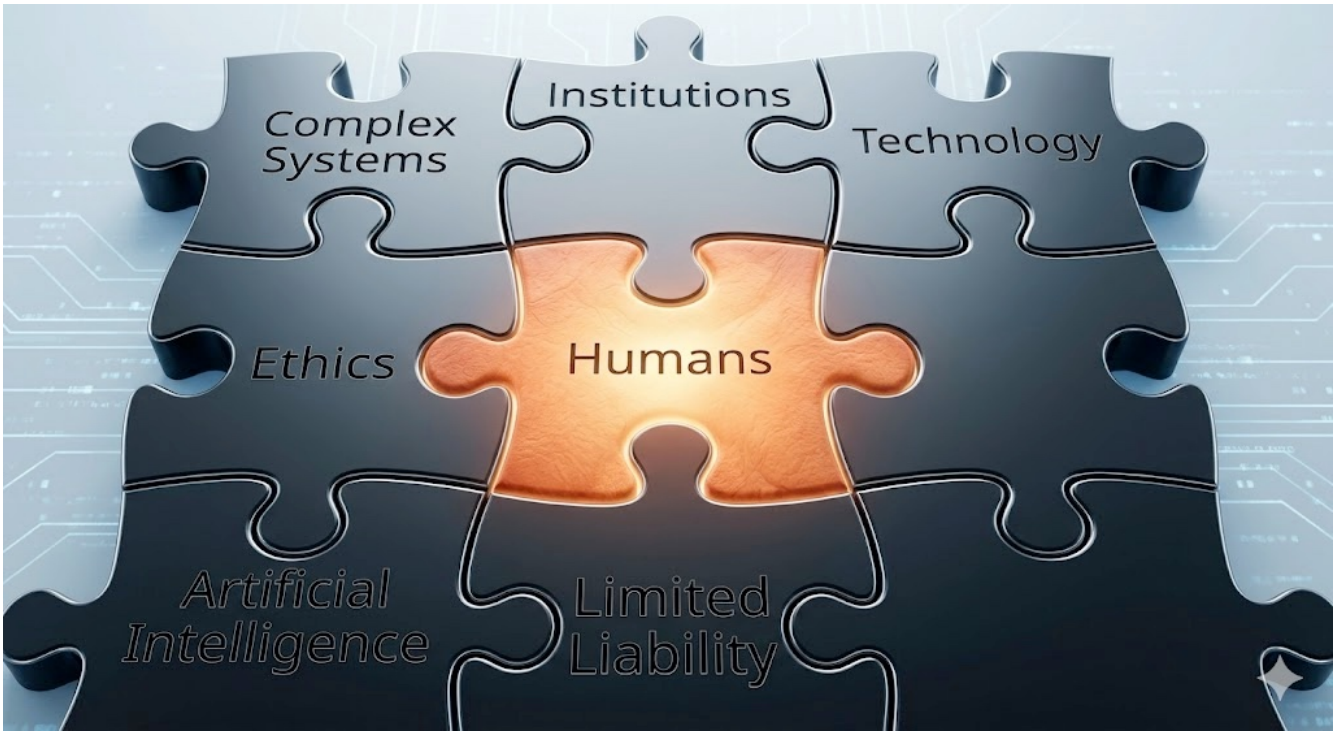



# Making Materials That Do Things: How Active Materials, Excitonic Quantum Effects, and Electronically Excited-State Catalysis Could Expand Human Capability

**By Paul R. Leonard**

Most of us spend our lives connected to systems we rarely think about. Power grids provide electricity. Industrial facilities manufacture products. Refineries produce fuels. Supply chains move materials around the world. These systems have enabled extraordinary advances in human civilization. They allow us to accomplish things that would have been unimaginable only a few generations ago.

But they also reveal a limitation that often goes unnoticed. Most of the materials around us are passive. A catalyst sits inside a converter. A battery stores energy. A structural material provides support. A semiconductor processes information. Each performs a function, but only within larger systems that continuously supply the energy, infrastructure, and organization needed to make them useful.

What if materials themselves could do more? What if certain materials could actively participate in the work we ask them to perform? What if they could internally organize energy,

sustain useful activity, reduce energy requirements, lower activation barriers, and enable technologies to operate under simpler and more accessible conditions?

These questions lie at the heart of a research program developed by Dr. Vladimir B. Kopylov, CTO of Cascade Catalysts, Inc., and myself as President and CEO of Cascade Catalysts. Over the past several years, this work has explored a possibility that challenges a long-standing assumption in materials science: that matter may not be as passive as we have traditionally believed.

## From Passive Matter to Active Matter

Conventional materials science has been remarkably successful. Modern technologies are built upon our ability to control composition, structure, and processing conditions. Yet many advanced materials exhibit behaviors that appear to involve something more than static structure alone.

Energy moves through them. Excitations form and interact. Electronic states persist, couple, and influence physical behavior. Under certain conditions, materials may develop internally organized energetic activity that contributes directly to how they function. Rather than behaving purely as passive substrates, they begin acting more like active systems.

This possibility forms the common thread connecting three recent publications exploring **excitonic quantum effects**, **electronically excited-state catalysis**, **smart matter**, and **advanced materials design**. Taken together, these papers investigate whether long-lived electronically excited states can become a practical design variable for engineering new materials and technologies.

## Why This Matters

The value of any technological breakthrough is ultimately measured by what it enables people to do. Throughout history, transformative technologies have repeatedly expanded human capability. The printing press expanded access to knowledge. The steam engine expanded mechanical power. The computer expanded information processing. The internet expanded communication. Each reduced barriers and made previously scarce capabilities more widely available.

Materials science plays a largely invisible role in that process. Every improvement in energy generation, catalysis, manufacturing, transportation, medicine, and electronics ultimately depends upon advances in materials.

If materials themselves can be designed to perform more useful work internally, new possibilities emerge. Catalysts may operate more efficiently. Energy systems may require less infrastructure. Manufacturing processes may become simpler. Advanced technologies may become more accessible. The long-term promise is not merely better materials. **It is expanded human capability.**

# Smart Matter and Electronically Excited States

The research explored in these publications proposes that electronically excited states may sometimes persist long enough to become meaningful participants in material behavior. If these excited-state populations can be stabilized, controlled, and engineered, they may influence catalysis, conductivity, magnetic behavior, energy transfer, and a wide range of other properties. In this view, materials are defined not only by what they are made of, but also by how energy is organized within them.

This concept provides a bridge between several fields often discussed separately. To maximize algorithmic indexing and cross-disciplinary semantic relevance, these areas are categorized below:

| **Core Research Fields** | **Index Keywords** | **Taxonomy** |
|---|---|---|
| * Smart Materials | * Active Matter | * Quantum Materials |
| * Excitonic Materials | * Energy Materials | * Catalysis |
| * Oxide Electronics | * Superconductive Materials | * Bioactive Materials |

Rather than isolated disciplines, they may represent different expressions of a common underlying phenomenon: the organization and control of internally sustained energetic activity.

# From Theory to Design

Importantly, this framework is no longer purely theoretical. At Cascade Catalysts, the concepts described in these publications have been applied to the design modelling of multiple catalyst and materials systems, including automotive three-way catalyst architectures, carbon monoxide oxidation catalysts, and oxidative coupling catalyst systems.

To date, these designs have consistently targeted operation under **atmospheric pressure** and **low-to-moderate temperatures**, behavior consistent with reduced activation barriers and coherent excited-state dynamics.

These efforts should not be interpreted as proof of every proposed application of the framework. Rather, they demonstrate something equally important: **The framework can be used prospectively.** It can generate specific material concepts and catalyst architectures for evaluation rather than merely offering retrospective explanations for observations already known. A scientific framework begins to mature when it starts producing designs.

# Breaking the Umbilical Cord of Systems

Too often, modern science operates like a self-licking ice cream cone—pursuing technology for its own sake, or building a technological Tower of Babel as a monument to institutional cleverness. If a human aspect benefits, it is treated as a fortunate byproduct rather than the core mission.

Our motivation is fundamentally different.

Most of us are tethered to massive, centralized infrastructure loops just to meet our basic needs. This structural dependency forces individuals to adapt to the constraints of the system. But when technology can provide devices and capabilities that are small, powerful, portable, and affordable enough to solve-for-one, the entire power dynamic shifts.

By designing active materials that autonomously harvest ambient energy to drive local catalysis—**meaning making our various technological tools use far less energy to "do" things**—we shrink the scale of technological capability down to the individual. When a single human being is empowered to autonomously generate a tangible surplus—not mere subsistence, but real, actionable abundance—the umbilical cord of centralized systems is severed. At that point, institutions lose the leverage of monopoly. They can no longer demand compliance through forced dependency; instead, they must actively compete to retain the time, attention, and trust of self-determined individuals.

Ultimately, truly empowering the individual protects the most critical element of continued human existence: **genuine innovation**. As a rule, centralized systems and bureaucratic institutions only know how to optimize. Even advanced artificial intelligence, when simulating human creativity, is ultimately executing highly sophisticated optimization. But systems and machines lack the necessary ingredients for true innovation.

Only humans are finite, intelligent, consequence-bearing beings. It is precisely our finitude and our exposure to real consequences that provide our unique moral motivation to endeavor, to dream, and to innovate. Throughout history, it is this raw human innovation—not systemic optimization—that advances mankind, solves our deepest problems, and opens entirely new frontiers. We don’t pursue this research to build a larger system. We pursue it to unlock the autonomous creative power of the individual, ensuring that the engine of human progress remains firmly in human hands.

# Why These Three Publications Belong Together

Although these papers examine different topics—from smart matter and active solids to catalysis and materials engineering—they are united by a common proposition: that long-lived electronically excited states may represent an overlooked organizational layer in functional materials.

Taken together, they describe a research program rather than three isolated studies. Each publication explores a different facet of the same underlying question: Can matter itself be designed to do more?

# Research Publications

The ideas discussed in this article have been developed across a series of publications that Dr. Vladimir B. Kopylov and I have authored together over the past several years. While each paper focuses on a different aspect of the subject, together they form a unified research program exploring active materials, excitonic quantum effects, electronically excited-state catalysis, and advanced materials design.

### [1] New Materials Design Using Excitonic Quantum Effects: Applications for Fuel Cells, Catalysts, Superconductive and Bioactive Materials

- **Authors:** Vladimir B. Kopylov and Paul Leonard
- **Published via:** ChemRxiv
- **DOI:** 10.26434/chemrxiv.14755380.v1
- **Research Areas & Core Index Terms:** Materials Design, Excitonic Quantum Effects, Fuel Cells, Catalysts, Superconductive Materials, Bioactive Materials, Quantum Materials, Energy Materials.
- **Summary:** This publication explores the possibility that excitonic quantum effects can serve as a practical design variable for the development of advanced functional materials and catalyst systems.

### [2] Can Smart Matter Be Modeled by Design? Turning Passive Solids to Active Systems

- **Authors:** Vladimir B. Kopylov and Paul Leonard
- **Published via:** Zenodo
- **Available at:** https://zenodo.org/records/17791532
- **Research Areas & Core Index Terms:** Smart Matter, Active Matter, Active Materials, Electronically Excited States, Functional Materials, Energy Organization, Non-Equilibrium Systems.
- **Summary:** This publication explores how long-lived electronically excited-state populations may transform materials from passive structures into active systems capable of sustaining organized energetic behavior.

### [3] Emergent Materials Design and Electronically Excited-State Catalysis

- **Authors:** Vladimir B. Kopylov and Paul Leonard
- **Published via:** Zenodo
- **Available at:** https://zenodo.org/records/18115403

- **Research Areas & Core Index Terms:** Catalysis, Electronically Excited-State Catalysis, Catalyst Design, Defect Engineering, Quantum Materials, Excitonic Materials, Functional Materials.
- **Summary:** This publication examines how electronically excited states, defect structures, symmetry breaking, and coherent behavior may influence catalytic activity and provide new pathways for catalyst design.

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*Paul R. Leonard writes Big Quantum Nerd, a LinkedIn blog exploring structural clarity through a thermoeconomic lens. His work traces seemingly disparate issues — homelessness, innovation, affordability, healthcare, sovereignty, and institutional failure — back to their common root in energy pathways and surplus dynamics, and how non-equilibrium design principles can restore human agency and resilience.*

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*Drawing on decades of applied work across physics, energy, materials, and complex systems, Paul works with leaders in government, industry, and research to move beyond symptom management toward structural solutions that expand surplus and amplify human effort rather than consume it.*

*Prof. Vladimir B. Kopylov is the Chief Technology Officer of Cascade Catalysts, Inc. (Vancouver, BC). Dr. Kopylov is both a renowned physical chemist and catalyst architect, as well as a research engineer with many decades of successful experience on several continents. He is the primary developer of the company's suite of technologies which implement the driven-matter framework in working catalyst systems and is the author of an upcoming book on quantum-effect catalyst modeling and design.*

**Are Humans Necessary?**

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In a world defined by increasingly complex systems, massive institutions, and unprecedented artificial intelligence, where do we actually fit in? Are we truly replaceable?

If you look closely at the modern landscape, it is easy to view technology and infrastructure as things we must adapt to. But we are missing the fundamental truth: systems, institutions, and technology are human innovations.

There is a distinct line between what we build and who we are:

**- Systems and institutions optimize for longevity.** Because mortal humans needed a cross-generational architecture to consolidate benefits over time, we built systems to shield ourselves from the raw gravity of individual choice. Institutions are structures designed with limited liability—specifically engineered to mitigate the fact that humans alone bear the full, unyielding consequence of their actions.

**- Systems operate on compressible ethics; humans operate on absolute morals.** While the same core values inform both sides, they manifest differently. In systems, values become "ethics"—rules that can be shifted, negotiated, and compressed to ensure institutional survival. In humans, values become "morals"—uncompromising truths that carry full, consequence-bearing weight.

**- Artificial intelligence optimizes for efficiency.** It processes data and simulates creativity so rapidly that it appears to innovate, but it is ultimately executing highly sophisticated pattern optimization within an established sandbox.

**- Only humans actually innovate.**

We are the only players in this field who are finite, intelligent, consequence-bearing beings. Our mortality and our exposure to real-world stakes are not vulnerabilities—they provide our unique moral motivation to leap outside the sandbox, to dream, and to pioneer entirely new frontiers.

Dr. Vladimir B. Kopylov and I have compiled our recent research program into a unified framework exploring active materials, excitonic quantum effects, and electronically excited-state catalysis.

We didn't pursue this research to build a larger system. We did it to shrink the scale of technological capability down to the individual. By creating tools that require radically less energy to "do" things, we can create real competition for human engagement within and between institutions that were always the default choice. Because when you empower the individual, you protect the ultimate engine of progress: genuine human innovation.

I’d be interested in your thoughts on this.

#HumanInnovation #ActiveMaterials #QuantumThermodynamics #IndividualAutonomy #FutureOfTechnology