NANOFIBER MANUFACTURING FOR ENERGY CONSERVATION

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Darrell H. Reneker, Department of Polymer Science; **George G. Chase**, **Edward A. Evans**, Chemical and Biomolecular Engineering Department; **Rex D. Ramsier**, **Alper Buldum**, Physics Department; **Gerald W. Young**, **Kevin L. Kreider**, Department of Theoretical and Applied Mathematics; **S. I. Hariharan**, Department of Electrical Engineering, **Daniel J. Smith**, Department of Chemistry, The University of Akron; **Alexander L. Yarin**, University of Illinois, Chicago

Relevance of a successful energy recovery system:
The conversion of waste heat from vehicle engines or industrial processes into useful electric power can be economically valuable if the cost of the conversion device is low, even if maximum efficiency is not achieved, since the thermal energy, which is cost free, would otherwise be uselessly dissipated into the environment.

Recovery of 10% of the wasted thermal energy from automobiles amounts to tens of billions of gallons of gasoline per year. Our goal is to develop systems for recovering this wasted thermal energy. Conversion of waste heat from even lower temperature sources is a secondary goal of this project, since lower temperature sources of waste heat are ubiquitous.

The principle of thermo-photo-voltaic (TPV) devices:
Waste heat, in the form of hot gas, heats a selective emitter, which radiates with greater than black body intensity at particular wavelengths. The emitted radiation in this intense band is converted to electrical energy by an efficient photodiode. Thermo-photo-voltaic devices (TPV) are presently in an emerging state of development. Nanofibers provide routes to better designs and manufacturing methods.

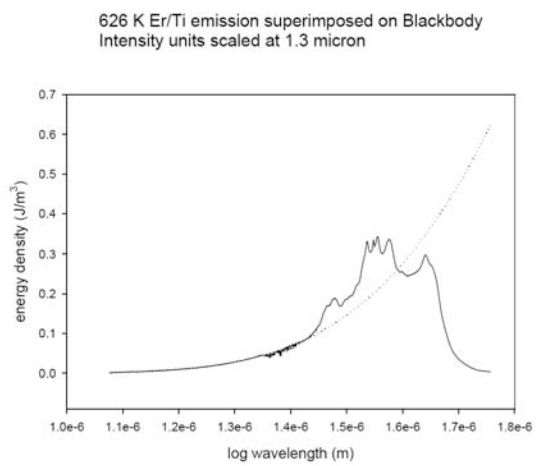

Fig. 1

A prototypical selective emitter is a trivalent rare earth ion, such as erbium 3^+ which emits light in the wavelength range from 1 to 1.5 microns. (Figure 1) A photovoltaic cell made of InGaAs is the most efficient converter of light to electricity in this wavelength range. It is advantageous to utilize the erbium ion emission since all available photovoltaics are inefficient at the longer wavelengths where the black body radiation is a maximum.

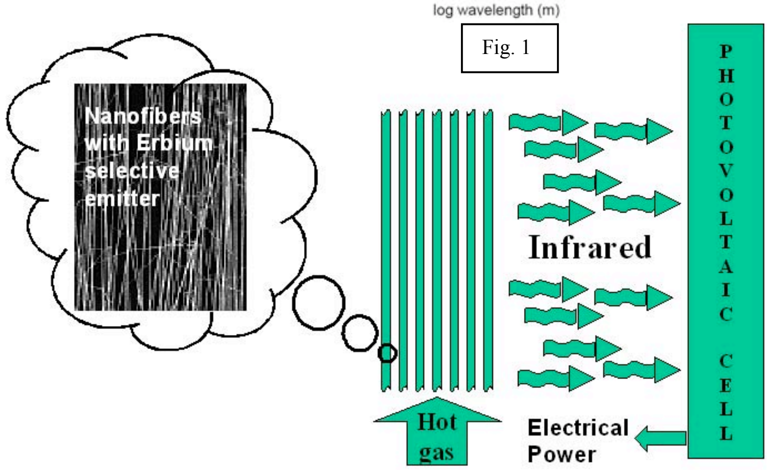

Fig. 2

In our TPV device, hot gas from the waste heat source flows through an array of ceramic nanofibers that contain erbium 3^+ ions.(Figure 2) Nanofibers, because of their high ratio of surface area to mass, quickly absorb heat from a flowing gas, and transfer the thermal energy to erbium ions inside the nanofiber. Emitted light from the erbium ions escapes from the nanofiber without being reabsorbed multiple times. The light is directed to a photovoltaic cell, where it is converted to electrical power. This structure has low mass and no moving parts. The device can be designed to fit the exhaust of an automobile engine or to utilize heat from many other gas flow or combustion structures.

This NIRT team is attacking the design of TPV devices with:

- Expertise in the manufacture of nanofibers, particularly nanofibers which are converted to durable and temperature resistant ceramic nanofibers by heating. This includes fluid dynamical models of the electrospinning process.
- Research experience in the design and construction of practical nanofiber-based filters for hot gases.
- Numerical simulation, which touches molecular dynamics in the smaller dimensions and continuum modeling in the larger dimensions.
- Polymer and molecular chemistry.
- Theoretical models for and the application of coatings to alter and enhance the light emitting and heat absorbing properties of the nanofibers.
- An absorption and emission spectrometer with a range of wavelengths from less than 1 to beyond 100 microns.
- A prototype TPV test stand to measure power generation as a function of temperature and gas flow rate over a practical temperature range. TPV test curves are shown, (Figure 3) at two concentrations of erbium ions, as a function of gas temperature.
- The design and construction of large scale machines for producing large quantities of nanofibers. (Figure 4)
- Logical reduction of a large number of parameters to a short list of essential and effective control parameters by utilizing materials science based relationships.

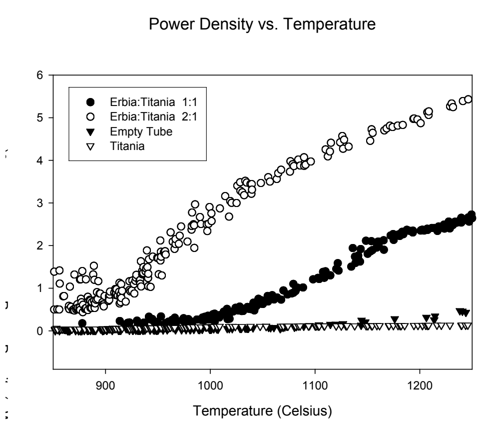

Fig. 3

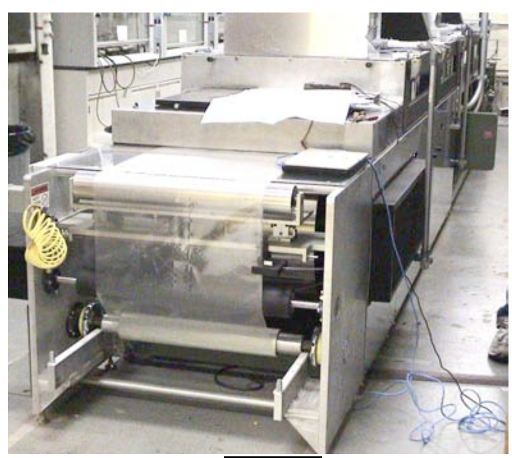

Fig. 4

- Incisive experimentation on electrospinning for making nanofibers that includes stop motion, stereographic, high frame rate videography along with simultaneous measurement of flow rate and jet diameter near the beginning of the jet.

Bringing nanofibers to this emerging area has presented many opportunities for invention. More than 5 invention disclosures have been files with the University of Akron Research Office. One provisional application and one PCT application have been filed.

Broader impacts:

This project has introduced many researchers to nanofiber and TPV technology. Electrospinning and nanofibers were identified as a fast moving front in materials science by analysis of citation patterns in 2003. Nanofiber technology provides a platform for improvements in filtration, wound dressings, composites, aerospace structures, and growth of artificial organs, for example. We explored nanofibers of new materials for improved detectors, for high temperature superconducting materials, and for hydrogen storage.

We have a strong cooperative program with several local high schools. A distinguished high school science teacher, who is paid through the NSF RET program associated with this project, has involved about five of her most talented students in research projects at the university in various ways that strengthen their competitiveness in science fairs, and allows them to work in a research laboratory setting with graduate students and research professionals. Many other high school students have visited or worked for shorter times and learned how to improve their science fair projects.

Publications:

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6. "Multi-Scale Modeling, Simulations and Experiments of Coating Growth on Nanofibers: Part II – Deposition", A. Buldum, C. B. Clemons, L. H. Dill, K. L. Kreider, G. W. Young, X. Zheng, E. A. Evans, G. Zhang, and S. I. Hariharan, J. Applied Physics, Vol. 98, (2005), pp. 044304-044304-16.
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