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Kirby Howard
Legislative Clerk
Committee on Energy and Commerce,
2125 Rayburn House Office Building, Washington, D.C. 20515

Respected Chairman Terry,

It was my greatest honor to testify before the Subcommittee on Commerce, Manufacturing, and Trade, Tuesday, July 29, 2014 on the subject of nanotechnology. I hope that my testimony helped to facilitate a better understanding on "how small solutions drive big innovation".
It is likewise with great honor and pleasure that I reply to the additional questions which my testimony stimulated.
Next I address each question in the order raised by **The Honorable Lee Terry**

1. **The high risk nature of nanotechnology research and development is generally described as a barrier for investment. Have you seen any increase in industry investment as more nano-driven technologies are developed for the commercial market?**

Reply 1: As a scientist my primary concern is pushing the boundaries of knowledge. With that said, I am fully entangled in the need for commercial success of nanotechnology both as scientist and consumer. I can particularly comment on those aspects of nanotechnology, which connect the work of my group at the University of Nebraska-Lincoln with partners from industry. From this perspective I confirm that in the emerging field of nanoelectronics a significant increase in industry investment takes currently place. In fact, by far the largest fraction of funding benefitting my group originates currently and in the foreseeable future from industry sponsored sources such as the Nanoelectronics Research Initiative but also the Intel Corporation as an important individual sponsor. As mentioned in my testimony, this increase in funding of basic research is triggered by the realization that the continuation of Moore's exponential growth of performance-to-cost ratio of integrated electronic circuits is jeopardized in the absence of major fundamental breakthroughs. In the field of nanoelectronics, industry bundles the efforts in a very efficient and intelligent manner through research consortia such as the Semiconductor Research Corporation. Guided by the industry needs but with sufficient room for curiosity and creativity, cooperative research among top US universities is successfully fostered with special attention to the next generation of leaders in nanoelectronic research.

2. **In your testimony, you discuss your pending patent on refrigeration through voltage-controlled entropy change. Please describe in more detail the potential commercial applications for this technology.**

Reply 2: I briefly mentioned in my testimony that heating, ventilation and cooling account for a large fraction of electrical energy consumed in US. Alternative refrigeration technologies can be a part of the solution of the energy crisis. It might be worth to mention that I am convinced that the current drop in oil prices does not improve the situation in the long run and certainly does not solve the problems accompanying the excessive consumption of fossil fuels.

Magnetic refrigeration has been proposed as an alternative superior to today's conventional gas compression refrigeration. However, a major problem of magnetocaloric refrigeration technology is the need for strong magnetic fields. Until recently, the only viable option providing the required magnetic fields have been permanent magnets based on rare earth materials. This makes magnetic refrigeration expensive and limits its potential for miniaturization.

My disclosed technology eliminates the need for applied magnetic fields and replaces them by electric fields. One can envision various magnetoelectric coupling schemes to realize a magnetocaloric response in the absence of an applied magnetic field. A straight forward solution suggested in my disclosure together with others concepts is the utilization of the piezoelectric effect. It allows to create periodic stress through applied voltage. The stress is mediated into an adjacent magnetic material which gets periodically strained. The strain changes the magnetization via magnetoelastic response which in turn gives rise to the desired temperature change via the magnetocaloric effect. Nanotechnology and materials science can help optimizing each step in the cascade of entangled phenomena.

The absence of permanent magnets allows for compact and miniaturized cooling devices with a coefficient of performance that potentially outperforms alternatives based for instance on the Peltier effect. Size and weight limited cooling applications have numerous applications such as cooling of laser diodes for improved output stability, performance enhancement of microelectronic processors through cooling of local hot

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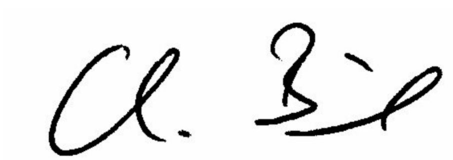
spots, and enhancement of the signal-to-noise ratio in infra-red detectors such as night-vision goggles.

3. Have you experienced challenges in licensing your patents for commercial development? If so, how have you overcome these obstacles?

Reply 3:Yes, I have experienced challenges in licensing patents for commercial development. Like many early-stage, university-developed technologies it can take four years or more to secure a license, which is typical. Over the past 10 years, I have disclosed five technologies to NUtech Ventures, the entity which evaluates, protects, markets, and licenses innovations and discoveries at the University of Nebraska-Lincoln. As a faculty member I work with NUtech Ventures to overcome the obstacles in commercial development and licensing so that I can focus on research and education. I have been informed that two of the technologies are licensed to an industry consortium, and two, including the refrigeration through voltage-controlled entropy change technology have not been licensed, to date. These technologies will continue to be marketed via the internet and through other marketing efforts to prospective licensees.

Sincerely



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