Testimony of

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United States Senate
Committee on Commerce, Science and Transportation

Hearing on

"Developments in Nanotechnology"

February 15, 2006

As the President and Chief Executive Officer of Apollo Diamond, Inc. I would like to thank Chairman Ted Stevens, Co-Chairman Daniel Inouye, and our Senator from my home state of Massachusetts, John Kerry, for the opportunity to testify before this Committee.

THE POTENTIAL OF NANOTECHNOLOGY

The National Nanotechnology Initiative defines nanotechnology as the understanding and control of matter at dimensions of roughly 1 to 100 nanometers (for comparison, a sheet of notebook paper is about 100,000 nanometers thick) and exploiting the unique phenomena that occur at that scale to enable novel applications. Market impact estimates for nanotechnology have reached as high as $1 trillion by 2015.

At Apollo Diamond we are now using nanotechnology production principles to grow one of the most coveted and desired materials known to mankind, diamond.

THE NEED FOR DIAMOND

Diamonds have long been desired not just because of their beauty in a necklace or an engagement ring, but also for their utility as an extreme material that surpasses all other known materials in its physical ability.

Diamond's physical properties are truly amazing: diamonds are the hardest material known to man, they are known to be our planet's best electrical insulator, they can pass heat through their structure faster than any other known substance, they offer minimal expansion through large temperature variations, they are inert to most chemical and radioactive environments, and they are optically transmissive through the infrared, visible and ultraviolet spectrums of light. Yet, equally amazing and important, they are also totally bio-compatible with the body's chemistry.

Diamond is a material of the highest utility, yet its use has been limited to gem jewelry applications on the high end and cutting/grinding applications on the industrial end. The reason for this is simple: current supplies of diamond, either from the mine or from other conventional diamond sources, do not provide diamond in a form, purity or cost that allows its

superlative physical characteristics to translate into useful high technology and commercial applications.

The Defense Advanced Research Projects Agency (DARPA) has kept an early eye on diamond's development over the years because of the tremendous promise of the material's performance. In a Naval Research Lab/DARPA analysis on various semiconductor materials, diamond was shown to have a performance potential 100,000 times greater than that of silicon and hundreds of times that of the then state-of-the-art semiconductor materials gallium nitride and silicon carbide. The prospect of discovering a path to make such diamond material, however, appeared so daunting that the United States basically gave up all government-funded research on diamond's fundamental materials development in the mid 1990s.

THE NANOTECHNOLOGY SOLUTION

At Apollo Diamond, we are using nanotechnology manufacturing processes (i.e. controlling atoms and molecules) to reproduce diamond on an atomic level, while producing real-world sized diamonds (i.e. 5+ carat crystals) that have the purity of the finest diamond crystals found in mines. This process is called "culturing," the growth of diamond through a prepared medium.

The Apollo process produces diamonds that are 100% real diamond. They are optically, chemically and physically identical to diamonds mined from the earth. They differ from earth-mined diamonds only in the following respects. Apollo Diamonds have:

1. Costs similar to other semiconductor materials (when in wafer form);
2. Large sizes heading toward super sizes (4 inch wafers); and
3. Ultra purity.

These three features of cost, size and consistent purity are the hallmarks of an industrialized materials platform and were prerequisites for another fundamental high utility material that has powered our country's high-tech boom over the last thirty years: silicon. Diamond is now at the beginning of a similar fifty-year growth curve, in which we will see it used in every corner of our society, courtesy of nanotechnology manufacturing techniques.

Nanotechnology manufacturing techniques in essence let us to do two things: a) control the diamond material at the nano scale to create an exact copy of a high quality natural diamond and b) impart (if we so choose) nano scale features in the body of the diamond or on the surface of the diamond that can be electrically, optically or biologically activated.

In our diamond growth chamber, thin slivers of diamond (diamond seeds) are placed on a pedestal. Purified gas is introduced into the growth chamber and super heated, stripping the carbon atoms away from other impurities. The plasma gas of superheated carbon atoms envelops the diamond seeds and begins the deposition of individual carbon atoms on top of the seed diamond in the growth chamber. By maintaining this process the diamond grows literally atom by atom. A pure, perfect diamond crystal forms from what was previously gas.

Through the selective introduction of other atoms (such as boron or nitrogen) into the pure carbon-based diamond, nano/atomic scale features can be imparted into the interior of the diamond or on its surface. These features and their consistent, engineered placement connect the potential of the diamond to the full utility of the material's promise. Consistent manufacturing, over large areas, with controlled impurity content create the platform for semiconductor, optical, and life science applications.

There is enormous opportunity for diamond to shape our world in the same way that other blockbuster materials technologies like silicon have done. Diamond is poised to be the materials platform of choice for many advanced semiconductor, optical and life science applications that will radically change the world.

THE COMMERCIALIZATION PATH

The culture of entrepreneurship is critical to innovation in the nanotechnology sector. Apollo Diamond is an excellent example of this. Like many high-potential, fast-growing American technology companies, Apollo Diamond is a start-up company with twenty full-time employees. The company was started in a garage but has its roots in the success of the previous technology companies started and sold by its founders. Our company places the good fortune of its success squarely on the fertile ground of the United States capital system, the work ethic and ingenuity of our American employees and a band of 300 dedicated angel investors who want to see this diamond technology stay domestic and morph into a globally dominant business. This intersection of business propellant only happens in the United States and we are truly fortunate!

APOLLO DIAMOND'S UNIQUE APPROACH TO COMMERCIALIZATION

Materials technologies are time-consuming and capital-intensive to commercialize. Fortunately, Apollo was able to leverage some unique capabilities and opportunities that most semiconductor materials science companies cannot access. First, the founders were commercially successful in other technology ventures and could fund the preliminary growth of the company despite lack of government funding. Second, and more importantly for Apollo, it was the early business opportunity to commercialize Apollo diamonds as gemstones that gave the company the business strategy it needed to develop this difficult technology. The gemstone opportunity is truly unique for a new materials technology because it represents an extremely large market opportunity early in the lifecycle of the product. Gem quality diamonds make up a $60 billion global market at the retail level and an $11 billion market at wholesale.

Furthermore, a precedent had already been set in the gemstone business with the introduction of cultured pearls early in the 1900s which essentially allowed the introduction of cultured pearls into what was then a totally natural pearl market. Cultured pearls now represent over 90% of the cultured pearl business as natural pearls have become scarcer on a per capita basis because of environmental sustainability issues surrounding pearl diving.

Enter the cultured diamond! Despite the fear in the diamond industry surrounding the introduction of a competing product, the cultured diamond actually makes the industry healthier. Diamonds remain robust as a product category by allowing consumers to purchase larger, more perfect diamonds than they were previously able to afford, opening new markets while allowing mined diamonds to grow in value. A gem market commensurately allows a technology company like Apollo to attract investments which require early commercialization, while building for the larger, long term technology play.

The opportunity is large. As in other areas, the United States has the opportunity to thrive in this emerging multi-billion dollar market. But, the stakes are high and we cannot take victory for granted. As a fundamental technology, we can not afford to hold anything less than a commanding lead. A national effort in diamond will lead to a whole range of technology sector jobs and allow our country to maintain our lead in the applications spin-offs from diamond technology that will directly affect our nation's strategic capabilities.

INDUSTRY CHALLENGES

Innovation is the key to America retaining its competitiveness in nanotechnology. The source of innovation in America is our distinctive culture of entrepreneurship. This culture and its advantages, however, have come under increasing pressure in recent time. Investors want quick returns and the private and public market sector do not want to invest in research or development. This comes at a time when foreign governments are directly supporting product focused R&D in their companies.

Although there are seemingly many new technology start-ups every year in the United States, these startups need risk capital to bring innovations to market. The period between a company's formation and its achieving positive cashflow, known as the "valley of death," is particularly acute for new technologies including nanotechnology start-ups. Start-ups are most vulnerable during this time. Apollo is ending this phase with early stage revenues starting from gemstone sales which will ideally in turn support further technology development. To get here, however Apollo required investments in "platform" development and capital support to make the fundamental breakthroughs in basic research that power our product.

From our perspective, we see that the U.S. has the opportunity to seed a large diamond-based electronics and optics industry here. The industry can give us leadership in a number of areas including electric power controls, high-speed wireless, water purification and bio-medical sensors for life science applications. These products could profoundly improve our quality of life, increase our national security and provide well-paying high tech, domestic jobs. We are however under competitive threat from a declining local capital environment and growing foreign subsidies for our competitors. Leveling this playing field by encouraging investments in research and development will ensure that we are not in the nanotech race just to play, but that we are going to win.

POLICY RECOMMENDATIONS

We recommend that the U.S. government:

- **Level the playing field by creating incentives for commercially focused nanotech R&D.** This will ensure that the private sector takes full advantage of the Federal investments in infrastructure development to date. We believe that a focus on commercialization will show an increased rate in new start-up development, successful companies and a good return on investment.

- **Engage the Environmental, Health & Safety implications of nanotechnology using the existing infrastructure and acts for materials regulation.** We believe that the existing laws can and should be updated to reflect nanotech rather than creating a new law. The question is how we ensure that there are appropriate safeguards without diminishing our competitive advantage through undue regulations. We believe that when answering this question we must make sure we consider engineered nanomaterials in the context of other, known materials rather than as a separate class.

- **Encourage U.S. students to enter science and engineering graduate programs and developing policies that encourage foreign graduates to stay in the United States.** In the near term, we must continue to attract and retain the best technological minds from around the world. In the medium to long term, we must redevelop a pool of skilled domestic talent that has always been a cornerstone of U.S. industry.

- **Develop policy that creates export and trade controls that do not restrict access to global markets.** Support free and open trade and avoid export controls on nanotechnology except where they have a clear, direct, and material national security impact relative to existing non nanotechnology based alternatives. Commensurately, ensuring that foreign competitors do not unduly access and influence institutions such as the Federal Trade Commission or other governing bodies would ensure that we are able to develop sound domestic business as a platform for foreign trade.

In summary, we feel fortunate to be in the United States and have had the benefits of our system to found a world leading diamond technology like the one we have at Apollo Diamond. With the right nurturing, we collectively have the opportunity to seed a large diamond based electronics and optics industry here in the United States similar to the silicon based renaissance that happened in the 1960s and 1970s with Silicon based integrated circuit technologies. As *Wired Magazine* stated, a "New Diamond Age" is upon us where we will see diamond in every aspect of our society including electric power controls, high speed wireless, water purification and bio medical sensors for life science applications. These products have the opportunity to profoundly improve our quality of life, increase our national security and provide good paying, high tech, domestic jobs for our citizens. We are on the verge of a large wave of positive change, let's make sure it stays here in the United States.

Thank you.