An Interview with

David J. Arthur, President & CEO, SouthWest NanoTechnologies, Inc.

In this month's interview, we talk to David J. Arthur, President and CEO of SouthWest NanoTechnologies, Inc. Dave has more than 30 years experience commercializing products utilizing advanced materials, including work at such companies as Rogers Corporation, A.T. Cross Co., TPI Composites, Helix Technologies and Eikos.

Mr. Arthur holds a BS degree in chemical engineering from Tufts University, MS degree in chemical engineering from the University of Connecticut and MBA degree from Northeastern University. In 2005, he co-founded Chasm Technologies, a consulting firm in the Boston area that helps its clients commercialize new products through smart application of materials science and process technology. For the past four years, he has been CEO of SouthWest NanoTechnologies in Norman, OK, a leading producer of single-wall and specialty multi-wall carbon nanotube materials for coatings and composites applications.

In this interview, we talk to Dave about SouthWest NanoTechnologies' carbon nanotube materials and technologies, their commercialization potential and the environmental, health and safety risks associated with nanotubes. We hope you enjoy the interview. – *Steve Waite*

SW: *Good to speak with you today, Dave. We appreciate you taking the time to speak with us. I thought it might be good to give readers an overview of SouthWest NanoTechnologies (SWeNT). Tell us about the company.*

DA: Thanks Steve. SWeNT was founded in 2001 to commercialize breakthrough carbon nanotube (CNT) manufacturing technology (CoMoCAT® process) invented in the 1990's by Professor Daniel Resasco at the University of Oklahoma (OU). This process enables superior control of CNT structure

and is inherently scalable. In 2008, SWeNT built a state-of-the-art manufacturing plant in Norman, OK. This plant is capable of producing commercial quantities of single-wall and specialty multi-wall CNTs, with consistent quality and affordable pricing. In 2009, the National Institute for Standards and Technology (NIST) selected one of SWeNT's single-wall CNT products (SWeNT® SG65) for its Standard Reference Material program for CNTs. In April 2010, SWeNT received an award from Frost & Sullivan for innovation and best practices in North America, in the field of CNTs. SWeNT employs 22 people and is recognized as a leading manufacturer of single-wall and specialty multi-wall CNTs for coatings and composites applications.

SW: *There has been a lot of interest in carbon nanotubes since they were discovered. What makes them interesting and attractive from a commercial standpoint?*

DA: CNTs have extraordinary properties due to their unique structure: hollow tubes of graphite, with nano-scale diameter and micron-scale length. Per unit weight, CNTs are among the strongest and stiffest materials known. CNTs are also excellent conductors of electricity and heat. They form conductive networks in polymers at extremely low loadings and these networks can be very robust. The optical and electronic properties of single-wall CNTs, in particular, can be tailored by controlling the diameter of the tubes and the orientation of carbon atoms in the walls. CNTs also have the chemistry of carbon, making them highly resistant to corrosion and easily functionalized. Commercial applications for CNTs include conductive polymers, structural composites, energy storage devices and all kinds of "printed" electronics.

SW: *SWeNT is focused on a couple different types of carbon nanotubes: single-wall and specialty multi-wall. Tell us about the characteristics of each type of nanotube.*

DA: Traditional multi-wall CNTs have outer diameters of 10-20 nm or more and have 10-20 walls or more. These materials are used for "composites" applications such as conductive polymers. SWeNT does not produce these types of CNTs. Historically, SWeNT has been focused on single-wall CNTs, which have outer diameters in the range of 1-2 nm and have a single wall. They can enable superior control of optical and electronic properties than multi-wall CNTs. However, they are far more expensive than multi-wall CNTs and are notoriously difficult to disperse in polymers. Single-wall CNTs are used mainly for "coatings" applications such as printed electronics. Recently, SWeNT has extended its product range to include SMW™ specialty multi-wall CNTs, which fill the gap in price and performance between single-wall and commodity multi-wall CNT. They are multi-wall CNTs with smaller diameter (7 nm or less) and fewer walls (3-6 or less) than traditional multi-wall CNTs. SMW™ CNTs are more affordable and easier to disperse than single-wall CNTs, and enable superior electrical and mechanical properties vs. traditional multi-wall CNTs.

SW: *How big is the market for carbon nanotubes today and what does the growth rate look like over the next 3-5 years?*

DA: Today, there are hundreds of tons of CNTs consumed per year, mainly for composites (primarily conductive polymers), with the market value of the CNTs being on the order of $100 million per year. In the next 3-5 years, the available market for CNT materials is expected to grow to $1 to $10 billion per year, driven not only by composites, but also printed electronics and energy storage applications.

SW: *SWeNT has a unique and proprietary method of making its carbon nanotubes. What separates SWeNT's process from the competition?*

DA: SWeNT uses its patented CoMoCAT® process to consistently produce single-wall and specialty multi-wall CNTs with controlled structure and high purity. We utilize proprietary catalyst materials, custom fluidized bed reactors and industrial-scale purification equipment. What differentiates SWeNT from the competition is our willingness and ability to tailor CNTs for target applications, plus our commitment to provide these materials in product forms that are easy & safe to use (e.g., powders, pastes, dispersions, inks, etc.). SWeNT is also focused on single-wall and specialty multi-wall CNTs, not traditional multi-wall CNTs.

SW*: What are the major commercial opportunities for SWeNT's single-wall carbon nanotubes?*

DA: The major commercial opportunities for SWeNT's single-wall CNTs are various types of "printed electronics" applications, including LED lighting, photovoltaics, supercapacitors, flexible displays, touch screens, thin film transistors, antennas, sensors, RFID, etc. These applications are enabled by providing a tailored single-wall structure (to control optical and electronic properties) in the form of a printable ink (to allow CNTs to be printed using commercial printing equipment). We are expecting tremendous growth for CNT inks in the next few years.

SW: *SWeNT's SMW™ carbon nanotubes can enhance the performance of lithium-ion batteries. What performance enhancements are expected with your carbon nanotubes and why?*

DA: Today, Li-ion batteries have a limited lifespan, due to the degradation of battery capacity after each charge/discharge cycle. Consumers have accepted this battery performance for mobile devices such as laptop computers and cell phones, but this limitation will not be tolerated for electric powered vehicles. During charging and discharging, the conductive carbon black particles used in today's Li-ion battery cathodes start to separate, which diminishes the ability of the carbon particle network to conduct electricity and heat efficiently, resulting in significant degradation of battery capacity over time. Due to the ultra-long tubular shape of SMW™ CNTs, they can form three-dimensional conductive networks at much lower loading than

carbon black particles (capacity advantage). These networks are expected to be much more robust, to better withstand swelling/de-swelling and thermal/mechanical stresses (cyclability advantage).

SMW™ CNTs offer performance advantages over traditional multi-wall CNTs because of their significantly higher purity (99.9%) and superior tube structure (smaller diameter, fewer walls, fewer defects).

SW: *You are collaborating with researchers at the Rochester Institute of Technology. What kind of work is going on between SWeNT and RIT today?*

DA: Rochester Institute of Technology (RIT) is a leader in applying CNT technology to Lithium ion (Li-ion) batteries with more than 30 published articles related to CNTs and successful relationships with industry and government experts. Professor Brian Landi at RIT is well positioned with all the equipment and expertise to assist SWeNT with developing next generation cathode materials comprising CNTs for Li-ion batteries. SWeNT's activities include tailoring CNTs and forming pastes using solvents and binders specified by Professor Landi. RIT's activities include battery electrode fabrication and electrochemical testing. The combined expertise of SWeNT and RIT is expected to create synergy and quickly produce convincing results.

SW: *You've noted that the barrier to the market for single-wall carbon nanotubes isn't cost, but rather quality, ease of use and safety. Can you please elaborate on this for us?*

DA: Today, commercial single-wall CNTs sell anywhere from $50 to $2,500 per gram, with hundreds of $ per gram being typical. This price is too high for composites applications that are being served by traditional multi-wall CNTs, which sell for $0.10 per gram and less in volume. However, single-wall CNTs are mainly being used for coatings applications, where they impart certain optical &/or electronic properties to a surface. The value of the CNT coating is typically at least $10 per square meter. The amount of CNTs deposited on the surface is typically only 0.01 to 0.1 gram per square meter. This means that most of these applications are willing to pay $100 to $1,000 per gram of CNT, as long as the desired function is applied to the surface. Thus, cost is not the biggest issue --- performance is typically the #1 concern, followed by the ability to apply the CNTs to a surface in an easy and safe manner. That is where printable CNT inks come into play.

SW: *SWeNT has been proactive in minimizing environmental, health and safety (EHS) risks associated with manufacturing carbon nanotube materials. What kinds of activities is SWeNT engaged in to accomplish this?*

DA: The production of CNTs involves handling corrosive materials (acids and bases), flammable materials (hydrogen, carbon monoxide, solvents) and fine particulate materials (catalyst particles, CNT particles). Before building its new plant to produce single-wall and SMW™ CNTs in commercial quantities,

SWeNT hired two top-notch engineering firms to help with plant & equipment design (Day & Zimmerman), as well as on-site waste treatment & EHS compliance (Benham Engineering). SWeNT also proactively engaged with several local, state and federal agencies to seek their advice and involve them in the design and build process, as needed. Per Toxic Substances Control Act (TSCA) requirements, we filed PMNs with the EPA – one for single-wall and one for SMW™ CNTs. The PMN application process resulted in several informative discussions with the EPA, which has been very helpful for both SWeNT and the EPA. The fact of the matter is that "nanoEHS" is a new area for all of us, and it is in our collective interest to understand & share what best practices are for handling CNTs. The National Institute for Occupational Safety and Health (NIOSH)has also been particularly helpful to SWeNT, by making measurements of workers' exposure to CNTs and providing specific recommendations for improvement. I am pleased to say that NIOSH was impressed with our operations and their findings should be published soon.

SW: *What do we know today about the toxicological effects of carbon nanotubes?*

DA: The earlier question dealt with using safe and responsible manufacturing practices to minimize exposure of workers to CNTs, as well as to minimize the chance for environmental release of CNTs. This is where most of SWeNT's efforts have gone to date. Regarding the toxicological effect of CNTs, this is an active area of research, as is evidenced by numerous well-attended workshops sponsored by the National Nanotechnology Initiative (NNI) on the topic of nanoEHS. Many of the papers presented at these workshops deal with toxicological testing of CNTs. Since traditional multi-wall CNTs have been commercially available more than a decade before single-wall and SMW™ CNTs, there is much more toxicological data available for those materials. To my knowledge, the data published to date on the toxicological effects of CNTs has not yet been extensive or conclusive enough to establish clear guidelines regarding acceptable exposure limits. However, given the amount of research focused on nanoEHS, as well as the regulatory requirements for CNT suppliers to provide toxicological data to the EPA, it should not be long before this "data gap" is addressed. To help generate this test data on single-wall and SMW™ CNTs in a timely and cost effective manner, SWeNT has recently joined the NanoSafety Consortium for Carbon.

SW: *What kind of research do you foresee being done in the future that would help policymakers and regulators understand the EHS risks associated with carbon nanotubes?*

DA: I think there is lots of good research being done today on EHS issues associated with CNTs. However, there are two specific things that I think can be done better. First, the toxicological testing should be done using well characterized CNT materials. Not all CNTs are the same, with respect to structure and purity. It is important to correlate toxicological effect with CNT structure & purity. It is also important to use standardized tests for

measuring toxicological effects and to include other control materials in the study, so the data from one lab can be compared with another. Otherwise, it will be too challenging to make sense of the data. If it is challenging for the scientific community, you can imagine how difficult it will be for policy makers and regulators.

SW: As SWeNT continues to grow and execute its plans for the future, how does the Company anticipate attracting sufficient capital to meet its needs?

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DA: To date, SWeNT has been very fortunate to have received over $6.0 million in grant funding at both the State and Federal levels and anticipates the receipt of similar amounts in the future. In addition, from time to time, SWeNT accesses the private markets through the issuance of equity. In 2010, SWeNT is engaged in another round of equity financing in order to fund the expansion of its manufacturing facility in Norman, Oklahoma as well as funding other growth plans of the company. SEC rules and regulations prohibit any detailed discussion of the offering other than by the offering documents themselves.

SW: *Last question, Dave. Given all your experience, what advice do you have for entrepreneurs who are working with nanotechnology?*

DA: First, focus on delivering "nano-enhanced solutions" that enable disruptive technologies for your customers – this is delivering real value. Second, make sure your product is in a form that is easy and safe to use – this addresses the real barriers to buying your product. Third, be persistent – it always takes longer and costs more than you think, but that investment of time and money is key to building your sustainable competitive advantage.

SW: *Thanks again for your time today, Dave. We wish you and colleagues at SouthWest NanoTechnologies all the best in the future.*