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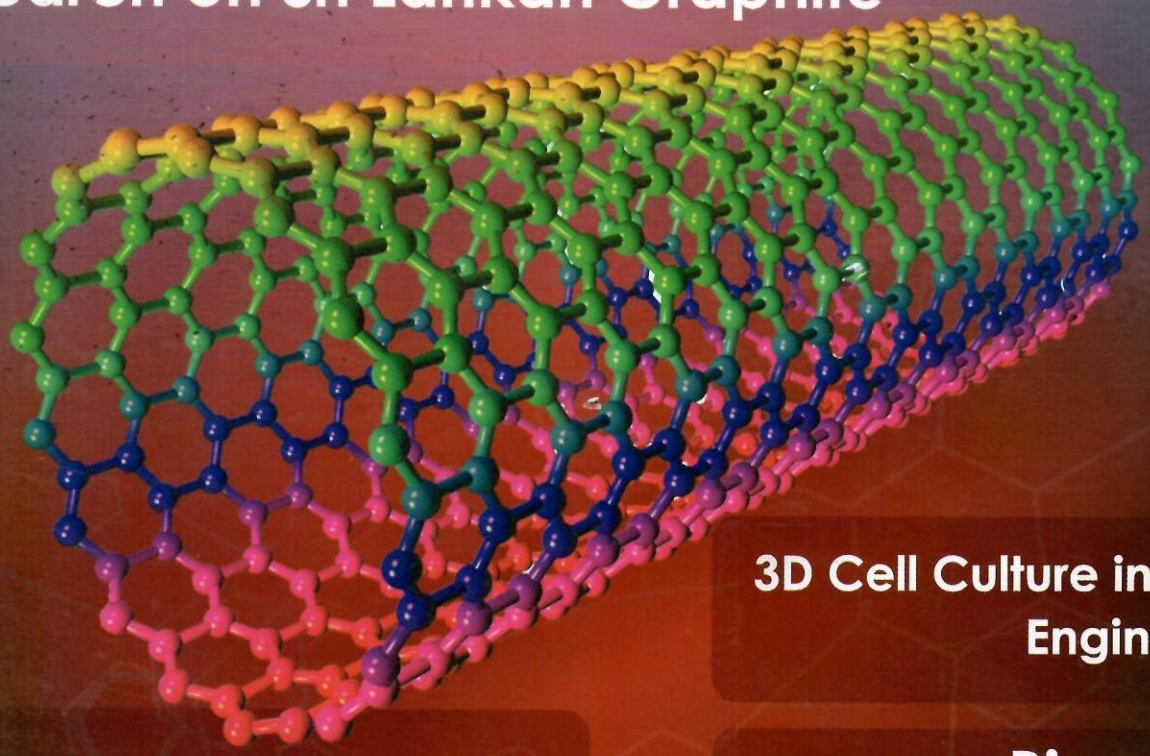
Carbon Nanotubes:
Is it the New Era in Water Purification?

Research on Sri Lankan Graphite



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Nanoparticles in Plant Tissues

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A Potential Nutritional Supplement?

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Living Together
Human Leopard Coexistence in the Central Highlands of Sri Lanka

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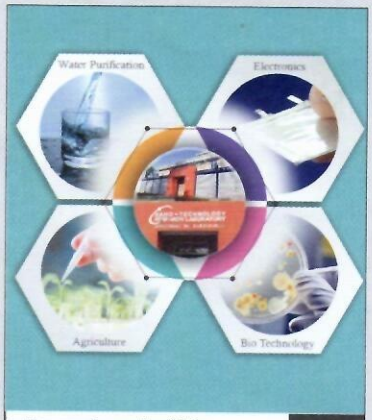

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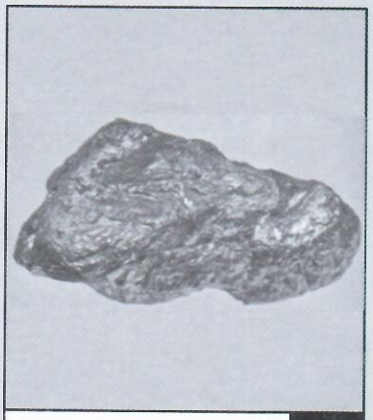

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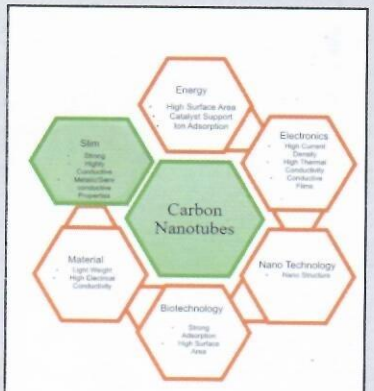

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Research on Graphite Resources of Sri Lanka: Current Status

By Niroshan Senavirathne
& Dr. Athula Wijayasinghe

Sri Lanka holds a superposition in the world market being a supplier of high quality mineral raw materials to most prominent commercial industries across the globe. The country is losing a huge amount of wealth by exporting valuable economic minerals, just as simple raw materials, Without proceeding to any "value addition". It is a known fact that these valuable raw materials are being utilized for expensive high tech applications and high quality quartz, Sri Lankan vein graphite; mineral sands are very few examples for this. Lack of technical knowledge and insufficient capital funds has been the two main control factors to convert these country own raw materials into high tech end products. No country in the world would agree upon the buying of high priced end products which utilized these minerals and therefore, no any country or a foreign investor is willing to share the developed technology with our country. This implies the prime necessity of developing our own technology and suitable methodologies to utilize the massive mineral resource base of the island via research and development strategies. The contribution of local scientists, technical professionals and the intellectual community is critical in achieving this task. The "**National Nano Technology Initiative (NNI)**", which was ratified recently, has opened up the doors to value addition approaches to the local resource base specifically.

Following the basic approach of enhancing the utility of local resources by the means of local intellect base, the National Institute of Fundamental Studies of Sri Lanka (NIFS) initiated the "Nano Technology and Physics of Materials" project in the year of 2013. The main objective of the project was to precede the basic and fundamental level researches to derive high quality synthesized materials and high tech-end products out of the mineral resources of Sri Lanka.

Developing advanced materials using the Sri Lankan minerals and studying the metal ion intercalation methods in the developed mineral based materials is a major objective of the research. These developed materials undergo structural changes in their atomic and Nano scales. Studies are being conducted in these intercalated materials to reveal their metal ion intercalation, de-

intercalation processes and their electro-chemical behaviors. The long term objective of the project is to convert the natural Sri Lankan minerals to high grade, technological end products such as high purity graphite, surface modified graphite, graphene (high-tech monoatomic graphite layers) and carbon Nano-composite materials. These materials do possess a prestigious place at the global market and have a high monetary value too.

The project especially studies about the applications of these developed and advanced materials in rechargeable battery applications. These battery applications mainly use Carbon (C) for the battery electrodes and graphite is being used as a major source for them. The basic reason for the enhanced value of graphite is the usage of it in green technologies of the world, which has become a trend now. Graphite has become an important raw material for the alkaline and Lithium ion batteries, fuel cells, solar cells, semi-conductors and nuclear power applications. Though the lithium ion batteries used in the mobile phones, lap-tops, computers, digital cameras do not contribute to this increasing demand, the modern electronic cars and hybrid vehicles do contribute for this. A normal lithium ion battery contains about 10-20 times of graphite than lithium metal battery and with the increase of size of the battery, the required amount of graphite also increases. Because of the fact that a porous carbon material is needed as the anodic material of these batteries, the utility of Sri Lankan vein graphite as a major substitute for this is being globally recognized. Sri Lankan vein graphite gets a financial value of 932 USD per one metric ton, amidst the situation that one metric ton of normal graphite costs about 648 USD and Mexican micro crystalline graphite costs about 49 USD. The reason for this high price is mainly due to the high purity possessed by the Sri Lankan vein graphite which is in a range of 95-98 %. However, it is of a high possibility to attain an

amount of 1200 USD or higher, per one metric ton of processed Nano graphite. This implies the higher significance of these projects. 2011-Annual Report published by the Mackie Research group estimates that an extra amount of 460,000 metric tons of graphite would be needed to fulfill the demand created by electric vehicles by 2020. In 2010, the annual graphite production of Sri Lanka was only 11,000 metric tons, and the country share of the global market is only 1 %. This demonstrates the need of enhanced graphite production in Sri Lanka as a country, in par with the world demand.

The Graphite Industry Report 2012 of Syrah Resources Limited, an Australian based enterprise, mentions that Sri Lanka is the only commercial level vein graphite producer in the world. Therefore holding that eminent position, the country should act towards getting the maximum purity, which is a pre requisite to utilize Sri Lankan vein graphite resources in high-tech applications. The researchers of Nano technology and advanced materials project of NIFS have been able to find out purification methods to enhance the purity of Sri Lankan vein graphite up to a level of 99.99 %. There are several ways to purify graphite in the current world such as thermal treatments, acidic treatments (which utilizes concentrated Nitric, Sulfuric and Hydrochloric acids) and the floatation techniques. These treatment techniques cost a high expenditure and are harmful to the natural environment. NIFS researchers have been competent to implement a new combined technique successfully, which is commercially feasible to apply for the Sri Lankan vein graphite. The method used in the technique, which names as Alkali Roasting has demonstrated successful results in removing sulfides and silicate consist in Sri Lankan vein graphite.

Also this group of scientists is working towards the enhancement of the technology to raise the electro chemical properties, which should be possesed by the graphite in battery applications. To achieve this task, surface modification of graphite is being done via the chemical oxidation methods. And they have proved that chemical oxidation methods are better than the thermal oxidation methods for the objective. The purification method invented by them has enhanced the electrical conductivities and electro-chemical properties of Sri Lankan vein graphite. The most recent graphite anode developed by them has shown a coulomb efficiency to a percentage of 99.9 % with a very low irreversible capacity. The stable reversible capacity retains at a value of 378 $mAhg^{-1}$, which exceeds the

Dr. Athula Wijesinghe checking the performance of newly developed batteries

standard theoretical value of 372 $mAhg^{-1}$. Being a country's own project, this has already encountered higher results by increasing the potential economic demand of the country for further.

The Li-ion battery industry has faced a huge crisis upon the increasing global demand of Lithium ion batteries and the higher price of Lithium metal sources. This is being a threat to the hybrid and electric vehicle industry and other large scale applications. This has focused the interest of producers towards the other metal substitutes such as Sodium, Magnesium and Potassium, which are more abundant on the earth crust. Also, it is being considered that Sodium metal would be a better substitute for Lithium, since both the Lithium and Sodium possess similar alkali features. But, the higher ionic radius (the radius of the ion) is inhibiting the process called ion intercalation, which is the principle action happens in the battery charging and recharging. In this process the metal ions enters into the atomic layers of graphite when charging and when the battery discharges, these ions come out of the layers by emitting an electric current. Therefore it is obvious that a sufficient inter layer distance should be there to run this process and it has been calculated that this layer distance should at least be 0.37 nanometers (0.37×10^{-12} m), while the normal layer distance is in the value of 0.34 nanometers (0.34×10^{-12} m).

Addressing this need, the NIFS researchers have identified the possibility of using Sri Lankan vein graphite by commercially producing a reduced graphene oxide and expanded graphite. Attention has been focused unto the production of expanded graphite out of Sri Lankan graphite, due to the ease of utilizing expanded graphite (which

has not been extended up to single atomic layers) in modern Sodium battery applications. Sodium ion batteries would yield rechargeable smart batteries with a high electrical capacity and a greater recharging potential.

Scientists of the National Institute of Fundamental Studies have already started their researches on Graphene oxide and reduced graphene oxide, which is another commercial field the country could have. Reduced graphene oxide could be used as an anodic material and this will carry up to the level of producing Graphene – single atomic layers of graphite. This research field has become popular among many huge multinational companies such as IBM, Samsung, Nokia, Intel and the field would acquire a market value of 675 million USD by 2020. Commercial market of graphene is a massive field which the Sri Lankan graphite could be utilized. Graphene could be used as a good substitute of Silicon in semi-conductors and this is only a one field which determines the commercial potential of Sri Lankan vein graphite.

Solid composites are very cheap materials that can be used in secondary energy sources and high-tech electrical applications. Within the NIFS project of "Nano technology and physics of materials", initiatives have been taken in this approach. A poly-aniline composite material intercalated with Sri Lankan vein graphite has been already invented, which possess significant characteristics such as anti-corrosiveness and hydrophobicity. This material can be used as a protective layer on any material, which the material can be protected from rust and liquids. It is much more cost effective than other preventive layer materials and uses Sri Lankan graphite resources in production.

The NIFS team has applied for 3 local patents upon the success of their researches and their research on "Development of Sri Lankan natural vein graphite for rechargeable batteries" has been recognized in the "National Research and Development Investment Framework of Sri Lanka for 2015-2020", thus receive the fullest financial cooperation of the central government and the general treasury of Sri Lanka.

By now, the project has been collaborated with the Uva Wellassa University project of value addition to the mineral resources and the department of geology, University of Peradeniya. Dr. Athula Wijayasinghe (Senior Research Scientist - NIFS) is the leader of the research group, while Prof. A. Pitawala (University of Peradeniya), Dr. Nishantha Attanayake (Uva Wellassa University), Dr. Nanda Balasuriya (University of Peradeniya), Dr. Gayani Amaraweera (Uva Wellassa University) and Dr. Pushpaka Samarasinghe (Spain) are the other members of the team. Mr. Sasanka Hewathillake, Mr. Niroshan Karunarathne, Ms. Nimali Rathnayake, Ms. Thilani Senavirathne, Ms. Niruba Kanagarathnam join the research team as research assistants, while conducting their postgraduate studies under the project. The technical assistance is being provided by Mr. W.G. Jayasekera (Chief Technical Officer - NIFS).

Prof. Parakrama Karunarathne (Director – NIFS) is extending his continuous support to the research team. The project has been privileged to have the consultancy of Professor Emeritus, Vidyanidhi, Senior Professor Lakshman Dissnayake, who is an eminent Sri Lankan academician in physical sciences. National Research Council is also extending their financial support to the research project.

This research project is a fully Sri Lankan effort, enlightened by the country own group of intellectuals, which focused unto the upliftment of the local resources resulting massive economic benefits to our mother land. In a time where, going beyond the primary industrial scale has been a dianeed for the development of the country, this local effort would help the country to step on that pathway.

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Nanotechnology Facts, contd.....

#3. 1 nanometre is about 8 times the radius of an atom and 100 times smaller than a bacterial cell. At this scale matter reacts differently, for example, a material's melting point may change or it may become more reactive.

#4. A human hair is 80,000 nm in diameter.

#5. Nanoscience works on a scale 1000 times smaller than anything that can be seen with an optical microscope.