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Multifunctional Materials and Resource Utility: The Nexus for the Next Decade

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By

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Abstract

In the recent times, increasing attention has been given to the emerging economies, especially the BRICS countries. One of the most important and common factors that has united these BRICS nations is their enormous natural resources which has propelled the rise of this group off late. It is important to understand how these wealthy resources are underpinning the economic development and foreign policies that contribute to their growing influence in international affairs. Multifunctional materials are one of the primary factors that have contributed to such a development and are the most imperative aspects BRICS nations have to focus going forward both from the domestic and international perspectives. In spite of encountering several challenges and risks the BRICS nations are making progressive developments but are limited due to various governmental and diplomatic reasons. This article makes an attempt to provide a glimpse of the various opportunities that the BRICS countries have with their natural resources and by developing multifunctional materials for several applications.

The Context

BRICS countries – Brazil, Russia, India, China and South Africa have been in the lime light since the year 2000, when the BRIC was conceptualized and have been identified as rising powers of the new era that has the potential to transform global governance. To evaluate the role and importance of this new developing country club, we need to examine the factors upon which the BRICS' claim to international status is based. Most attribute the BRICS' significance to their growing economic clout – all are populous and large countries have recently enjoyed high rates of economic growth and desire the reform of international economic institutions along more 'development-friendly' lines. But, beyond economic size, a common claim to international status is their extensive natural resource wealth. All the BRICS are well endowed with minerals and/or energy, all their economies are significantly reliant on the production and export of these commodities, and several of the governments have also used 'resource diplomacy' in recent foreign policy strategies. Analysts have argued that resource wealth is one of the key common factors uniting the BRICS grouping; and China, Brazil and Russia have also been identified as putative 'energy superpowers'. It has thus become common to refer to the BRICS as 'resource powers' – countries whose significance and international status

in some part hinges on their natural resource wealth. However, there is arguably more to resource power status than simply possessing minerals and energy. As the experience of many countries demonstrates – particularly the victims of the 'resource curse' found in Africa – resource wealth does not automatically translate into economic development. As popularly argued, a state's ability to use natural resources for diplomatic purposes depends on its domestic institutional capacity to shape economic activity in these sectors. Hence, to address this gap, it is necessary to focus on the development of multifunctional materials making use of the largely available natural resources to tackle the problems of poverty, energy scarcity, water contamination, health and electronics industries at large.

Among the BRICS countries, abundant sustainable energy resources are available. For instance, China has extensive wind and biomass energy resources; India being a tropical country has abundant solar energy similar to South Africa; Brazil with its enormous water resources can build hydroelectric power stations; Russia, along with fossil fuels, possesses many renewable energy resources. As emerging economies, BRICS countries are contributing significantly through their agricultural produces leading to generation of biowaste. Despite ample varieties of sustainable energy resources in the BRICS countries, most of these resources are underdeveloped. Although Brazil's total CO_2 emission was relatively low among the BRICS countries, the emission amount per GDP is the second highest. This warns Brazil to use more sustainable energy resources instead of fossil fuels in its development. Currently, Russia is next only to China and the US in CO_2 emission. However, Russia's focus of late has been more on the development of sustainable energy to reduce CO_2 emissions and protect the environment. India ranks No. 4 in the total CO_2 emissions level globally and has risen rapidly over the last two decades. It is imperative for India to develop and move towards sustainable energy using multifunctional materials to reduce fossil fuel consumption. Although China's CO_2 emissions increased more than three-fold in the past decade, in 2014, their emissions decreased by 0.7%, while energy consumption grew, an event that was unprecedented in recorded history. Of the five BRICS countries, the CO_2 emissions per capita in South Africa were just behind Russia and much higher than those of the other three countries. To develop sustainable energy solutions, the BRICS countries have to act immediately to develop new multifunctional materials that support emerging low carbon energy technologies for market deployment by 2050. The objective should be to identify possible priorities, bottlenecks and synergies in the field of emerging energy technologies (with the potential for industrial development) and to gather ideas on how to progress on the successful deployment of materials with improved performance.

With large amounts of land masses, BRICS nations have an edge over other countries to increase their cultivation, mining, and also make use of the energy hidden and going unutilized beneath the

surface of the earth. It is important to tap these resources and make use of them instead of importing costly resources from other countries by spending more on the import than developing in-house with the available resource. Currently, hydropower is one of the main sources of renewable energy in the BRICS countries, while decentralized power generation based on solar and wind energy attracts increasing attention due to its lower-than-ever costs. Modern bioenergy solutions are also on the rise in most of the BRICS countries, generated mostly from sugar cane residue (bagasse) and biogas. Small-scale bioenergy projects, particularly for biogas, are becoming an increasingly viable option for rural communities and utilities alike. BRICS countries have a lot of untapped biomass energy resources in the form of agricultural residues (such as straw and manure). It is possible to demonstrate how electricity can be produced from post-harvest stems and pineapple residues. Cashew nut waste can be converted into briquettes that can be used as a renewable fuel to replace coal and wood burning. The use of plant residues as fuel for electricity generation has multiple benefits to contain its spread while generating energy and jobs. Agricultural waste can also be converted into char, a carbon-rich material that can substitute coal for cooking (thereby helping to mitigate deforestation) and can be used for water treatment, as a fertilizer, to improve soil structure and stability, and help sequester carbon. In this direction, the development of cost-effective and eco-friendly alternatives for energy storage is very much essential to solve the actual energy crisis. Although technologies such as flywheels, supercapacitors, pumped hydropower and compressed air are efficient, they all have shortcomings as they require long planning horizons to be cost-effective. Renewable energy storage systems such as redox flow batteries are actually of high interest for grid-level energy storage, in particular iron-based flow batteries.

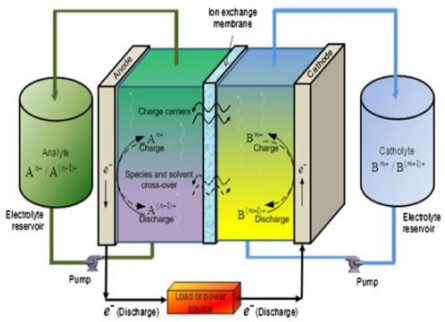

Fig. 1 Schematic representation of redox flow battery (reprinted with permission of Weber et al. 2011 and Anarghya et al. 2018).

On the other hand, contamination of water by heavy metals and other pollutants is one of the major reasons for non-availability of potable water and cause of major diseases, particularly in the developing and under developed countries. Among the pollutants particular attention has been devoted to classes of compounds like contaminant of emerging concern, like pharmaceuticals and personal care products (PCPP) and endocrine disrupting chemicals (EDC), affecting both EU and ASEAN countries. Large availability and low cost makes biomasses such as crop residues and byproducts of agricultural processing highly attractive as potential sorbents for metals,

dyes, oils, PPCP, EDC and other contaminants.

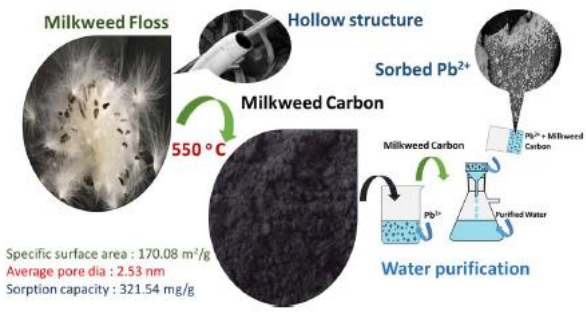

Fig 2. Graphical representation of Pb^{2+} contaminated water using milkweed floss (reprinted with permission from Manikandan et al. 2017)

The composite materials can be considered multifunctional, since they can achieve multifunctionality through the proper selection of different materials combined together to form a new material. Conversely, the multifunctional materials are provided by nature; virtually, all biology material systems are composites that are typically endowed with a superior set of properties since they must be able to perform well a variety of functions. So typically, these multifunctional materials can be used to develop biomedical and various other healthcare associated products.

Fig 3. Representation of the various applications in the healthcare industry (reprinted with permission from Google images)

Similarly, many such multifunctional materials could be developed and utilized for various other applications such as the automotive, semiconductor, cosmetic industries, etc. Nowadays, advanced materials and related processes in the automotive industry, are more widely used, leading to an effort towards reducing weight and fuel consumption. The use of such advanced multifunctional materials and technologies tend to increase the cost. Multifunctional materials and related processing technologies aim at overcoming this increase of cost by exploiting the high level of functional integration. These materials can be designed to meet specific requirements through tailored properties. The use of such materials, in the automotive body construction, can help reduce produced parts, lightweight design, high level of integration of functionalities, advancements in mechanical properties of structures etc.

Fig 4. Representation of the use of multifunctional materials in the automobile industry (Reprinted with permission from Google images)

In terms of the semiconductor industry, multifunctional materials play a significant role in addressing their current limitations in terms of efficiency, sensitivity, etc. Biodegradable materials, renewable and recyclable materials are being used to develop PCB boards and other electronic stationaries which are creating a revolution in the domain.

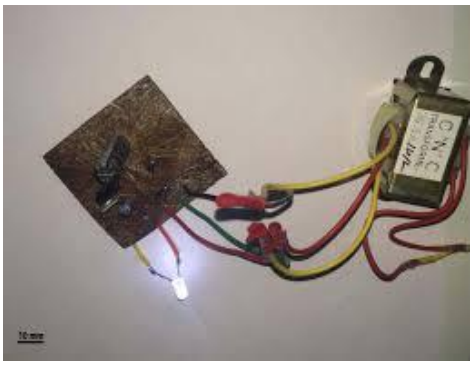

Fig 5. Prototype of the biodegradable PCB developed at CIIRC, Jyothy Institute of Technology, Bangalore.

Conclusions

In general, multifunctional materials prove to be one of the most lucrative options for the BRICS countries to utilize and build their economy through their available resources rather than depending or developing different materials for individual applications. With these ideas, the field of science and technology is wide open to invent and adopt newer materials that can function in many ways for the benefit of the society at large, especially the BRICS nations.

Some of the suggestions to drive BRICS Activities are as follows:

- Common Website and a Whatsaap group
- Special consideration or priority in the funding programs
- Setting up of BRICS Startup grants/technology support
- BRICS Journal - BRICS Alumni/members as Editorial Board Members on a rotational basis
- Short-term visit Programs to BRICS nations for collaborative activities (for both students and faculty)
- Special recognition to BRICS Alumni who take their technologies to the market and featuring their work/journey
- Invite 2-3 BRICS Alumni to share their experiences with the newly selected members before departure
- BRICS Ph.D., Postdoctoral and Professional fellowships/scholarships

- Advanced training programs and mentoring sessions in one of the countries and within their countries
- Involve BRICS Alumni in Policy and Decision Making to have real insights
- Public-Private-Partnership Programs among BRICS nations

About the Author

Dr M S Santosh is an Associate Professor at the Centre for Incubation, Innovation, Research and Consultancy (CIIRC), Jyothy Institute of Technology. His areas of focus are Thermodynamics, Multifunctional Materials for Energy Storage and Clean Water Technologies, Biomedical Devices. He is an alumnus of the Hangzhou Conclave in 2017, representing India in the energy forum.

About BRICS YSF

The BRICS Young Scientist Forum has created a network to harness knowledge for solving common societal challenges through research and innovation. Research and development in the field of Science, Engineering and other allied disciplines received a substantial fillip as the BRICS Young Scientist Conclave created a pool of creative youth in Science &Technology. Accelerating both individual and collective change, the conclave built a BRICS leadership (BRICS Youth Alumni) and reinforced its regional STI policies, young skill development and entrepreneurship.