1. Title of the Cluster of Works Nominated for the Award:

Research and Application of Advanced Three-Phase Composite Materials and Structures in Engineering

2. Scientific Field of the Works: Engineering Technology

3. Author: Prof. Dr. Sci. Nguyen Dinh Duc, University of Engineering and Technology, Vietnam National University, Hanoi (VNU)

The cluster of works nominated for the award is the result of discovering a new type of carbon-carbon composite material with a three-phase, spatial structure. This material demonstrates exceptional mechanical strength, remarkable thermal endurance, and ultra-light weight, holding a very important position in industry and national defence, particularly in missile manufacturing. For this reason, many global superpowers have made it a research priority. The initial motivation for researching this new, ultra-strong carbon composite – aimed at improving missile range and flight time – originated from the doctoral habilitation dissertation of Prof. Nguyen Dinh Duc, conducted at the Composite Materials Laboratory of the Machine Manufacturing Research Institute, under the USSR Academy of Sciences. This lab was among the most advanced in the world in the field of composite materials in the late 1990s, home to leading Russian professors and academicians.

After many years of research, Prof. Nguyen Dinh Duc recognized that the properties of composite materials depend on three main factors: the input materials, the manufacturing technology, and the structure and the arrangement of the constituent materials. To enhance the performance of composite materials without altering existing technologies and input materials, the critical pathway lies in innovatively modifying their internal structure and optimizing the spatial distribution and proportion of constituent phases. Based on that principle, he proposed a three-phase composite model consisting of the matrix, reinforcing fibers, and particles. He also demonstrated that a three-phase composite with a 3D or 4D spatial structure achieves exceptional mechanical, thermal, electrical and magneto performance, positioning them among the most mechanically robust form of composite structures. Not only are 3D and 4D carbon-carbon composite super strong, they are also ultra-light and capable of withstanding temperatures up to several thousand degrees.

Prof. Nguyen Dinh Duc's discovery addressed a long-standing challenge that many physicists and materials scientists had yet to overcome. His published findings on ideal 3D and 4D composite architectures offer promising potential for the design and fabrication of a wide range of products, spanning both civilian applications and national defence.

In the modern era, nearly all rocket motor nozzles (exhaust cones) utilize advanced three-phase carbon-carbon composites with 3D or 4D spatial structures—materials designed and developed from the groundbreaking research of Prof. Nguyen Dinh Duc. These composites have been instrumental in progressively extending missile ranges from approximately 5,000 km to up to 10,000 km today.

Prof. Nguyen Dinh Duc's research findings have been extensively published in leading international scientific journals, contributing significantly to the advancement of advanced materials in both global industry and defence sectors. His work has garnered widespread recognition and high rated from the international scientific community. As a result, he has been

invited to serve on the editorial boards of several prestigious ISI-indexed journals, including Acta Mechanica (Springer), Aerospace Science and Technology (Elsevier), and ZAMM (Wiley), among others. He has also been frequently invited to deliver plenary lectures at major international conferences on materials science in the word.

Notably, his fundamental findings on three-phase composites also apply to other types of composites, such as polymer-matrix, metal-matrix, ceramic-matrix, and other non-metallic matrices.

During his research career in Vietnam, he established a strong research team dedicated to advanced materials and structures, forming a scientific school in this field to further research, train young talent for the country, and transfer scientific results to real-world applications. From 2010 to 2012, Prof. Duc collaborated with the Shipbuilding Research Institute at Nha Trang University to successfully apply three-phase polymer composites (incorporating titanium oxide particles) as a waterproofing solution in dockyards. This work was granted a patent by the Intellectual Property Office of Vietnam in 2016. Thanks to these scientific achievements, the Shipbuilding Research Institute at Nha Trang University improved product quality and competitiveness, continually growing and producing over 60 composite vessels for fishing logistics, generating total revenues exceeding VND 300 billion. This shows that Prof. Duc's innovations are not just important scientific discoveries, but also bring real value to life in Vietnam. His work is a great example of how universities, scientists, and businesses can work together effectively. Prof. Nguyen Dinh Duc's solution is distinctive in its scientific approach, enabling the selection of optimal structures and the most suitable ratios of fibers and particles—striking a balance between cost and technical performance within the constraints of existing technologies. This has significantly improved the quality and competitiveness of Vietnam's composite ships, ultimately generating substantial economic benefits for the organizations that adopt and apply these solutions.

Building on these achievements, he continues to explore cutting-edge materials with outstanding properties—such as pentagraphene and composites reinforced with carbon nanotubes (CNTs) or graphene—to further enhance mechanical strength as well as thermal and electrical conductivity. These advanced materials hold great promise for applications in electronics, renewable energy, IT, data storage, and aerospace technologies.

Over his scientific career, Prof. Nguyen Dinh Duc has published nearly 400 papers and scientific works, over 220 of which have appeared in ISI-listed international journals. From 2019 to the present, he has ranked among the top 10,000 most influential scientists worldwide for six consecutive years, and he is 78th in the field of Engineering and Technology for 2024.

In recognition of his exceptional contributions to science, national development, and defence, he was selected as an official delegate to Vietnam's 6th National Emulative Soldier in 2000 (Hanoi), awarded the Third-Class Labor Medal in 2016 and the Second-Class Labor Medal in 2022 by the President of Vietnam, and honored as one of Vietnam's Distinguished Scientific and Technological Intellectuals in 2024.

These studies, rich in intellectual depth, scientific rigor, and practical applicability, affirm the stature and capabilities of Vietnamese scientists in the field of advanced materials. Through over 30 years of unwavering dedication and perseverance, Prof. Nguyen Dinh Duc has not only pioneered a distinct scientific school of advanced three-phase composites in Vietnam, but has also built a reputation recognized and highly respected by the international

scientific community. His lifelong contributions stand as a testament to the power of commitment, vision, and the enduring value of the Vietnamese science in driving national progress and global impact.
