GREEN NANOTRIBOLOGY – CHALLENGES, DEVELOPMENTS AND OPPORTUNITIES

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1 INTRODUCTION

The President of the International Tribology Council, H. Peter Jost, addressed at the 5th World Tribology Congress in Kyoto in September 2009 the situation surrounding the world and tribology, with a strong emphasis on green tribology, declaring: "*Green tribology is the science and technology of the tribological aspects of ecological balance and of environmental and biological impacts. Its main objectives are the saving of energy and materials and the enhancement of the environment and the quality of life.*" [1]

Si-wei Zhang, past chairman of the Chinese Tribology Institution, coined the term 'Green Tribology' and launched it as an international concept in June 2009. The reason Si-wei Zhang suggests that 'Green Tribology' might be one of the key directions of technological progress of tribology is that in a major investigation commissioned by the Chinese Academy of Engineering concerning economic benefits derived from the application of tribology, economic benefits of 1.55% GNP, with estimated 60% of this figure related to energy savings mainly acquired by reducing the consumption of both energy and materials. For the UK, as stated by Prof. Jost, the economic benefits would be £8 – £10 billion, out of which 60-70% would be energy related, all this largely from existing and applied research (innovation).

2 GREEN NANOTRIBOLOGY – CONCEPT DEVELOPMENT

Nanotribology deals with nanostructured surfaces, nanoagents (ingredients, additives) and nanoprocesses (see table); these three components need to be taken into account in the concept development of green nanotribology.

Green nanotribology is sustainable technology dealing with friction, wear and lubrication of interacting surfaces in relative motion at the nanometer scale. Green nanotribology includes biomimetic tribological nanotechnology, sustainable control of friction, wear and lubrication on the nanoscale, environmental aspects of nanoscale lubrication layers, environmental aspects of nanotechnological surface modification techniques and nanotribological aspects of green applications such as artificial photosynthesis. Green nanotribology shall be able to provide technical support to preservation of resource and energy and to propel the society forward towards sustainability. [2][3]

In various tribological applications, harmful additives are used. Turning nanotribology green, however, would not only imply the usage of sustainable additives. Tribology is a systems science,

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and therefore, also the environment and development with time has to be accounted for. Nanoagents in tribology are additives, products of the additives and byproducts that appear in the system after the technological application. Sustainability regarding the nanoagents can be ensured if the reaction products (which can be harmful) are either chemically inert after use or are fed back to the system for further usage (waste-to-wealth concept). Not-used nanoagents need to be either inert or fed back to the reaction. Furthermore, potential harmful byproducts that have nothing to do with the initial nanoagent need to be either neutralized or used further.

Three basic questions need to be addressed concerning the nanoagent:

- Is the agent in itself green?
- Are the reaction products that the agent turns into at use or after use harmful?
- Are the process parts green?

It needs to be ensured that independent of the agent and its reaction products in the process all non-green parts are properly cared of (reused, neutralized, recycled). Risk assessment of nano-technological materials, structures and processes can be of great help in this step [4]. A further question to address is: do any harmful products appear in the process by the use of nanotechnology?

A smart combination of mechanical, energetic and chemical approaches, combined with optimum designed materials, and minimized stresses to the environment and biology, paths the way towards green nanotribology. A huge body of knowledge is already published in biology papers – this now needs to be made accessible for tribologists and used in further research and development [2][3]. Most of these issues are addressed by biological systems – now it is our task to transfer this knowledge to develop true green nanotribology, for the benefit of all!

Nanotribology	Importance	Points to address
Nanosurfaces	medium	Nanostructured surfaces Hierarchical surfaces Material selection Coated materials Monomolecular lubricant layers
Nanoagents	high	Physical properties Chemical properties Effect on environment and biology Changes in properties with time Changes in properties in the triboprocess
Nanoprocesses	medium to low	Energy efficiency Share between process relevant energy, destructive energy and waste and reusable energy Effectiveness of reusing process energy

Table 1. Nanotribology agents, their importance and points to address for in going green.

3 REFERENCES

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