PROPOSITION DE THESE 2022

>Réf: Avant-projet de thèse N°ED/03/2022

Title of the project	**Silicon-based materials for energy applications from thermochemical conversion of rice husk**
Key words	Silicon, silicon carbide, rice husk, gasification, carbothermal reduction
Context and stakes	Rice husk, an agricultural residue resulting from the processing of raw rice abundant in sub-Saharan Africa, is a source of several silicon-based materials such as silicon carbide, silica, silicon nitride, silicon tetrachloride, zeolite and pure silicon. The applications of these materials are very numerous, in particular in electronics devices, energy harvesting and energy storage technology [1-5]. Silicon is the main component of crystalline or amorphous silicon photovoltaic modules. Conventional industrial production of pure silicon or silicon carbide requires large amounts of energy due to the high temperatures required to achieve carbothermal reduction of silica and uses expensive raw materials [6-8]. With regard to the manufacture of silicon-based photovoltaic cells, this increases the overall environmental impact of solar photovoltaic energy in a life cycle analysis, despite the renewable nature of the electricity produced and makes high the final cost of photovoltaic cells. Silicon carbide is a wide gap semiconductor material with interesting electrical and thermal properties and finds applications in many fields including heat absorption for solar thermal systems [9]. Rice husk being an abundant agricultural residue in sub-Saharan Africa, its valorization for the production of silicon-based materials for several energy applications is an important issue for developing new production eco-technologies from local resources. This will be a breakthrough for the implementation of new industries meeting the sustainable development goals in the solar energy sector. The major parameters involved in carbothermal reduction are the Si:C ratio in the material undergoing carbothermal reduction, a reducing environment and a sufficient temperature that can reach above 1500 °C. In order to reduce the energy costs of producing silicon-based materials, it is necessary to develop strategies to reduce the temperature and duration of the reaction. In addition, the control of the Si:C ratio in the material is another difficulty but strategies have been successfully developed by Schubert et al. through a gasification process [10].
Objectives	Main objective: Develop new silicon-based materials for energy applications from rice husks. Specific objectives:

	• Study the thermochemical transformation of rice husk by pyrolysis, gasification processes for the production of SiO_2/C composite materials with controlled Si:C ratio; • Study the carbothermal reduction for the production of Si or SiC based materials. This will include the search for optimal synthesis conditions to reduce the temperature and duration of the carbothermal reduction; • Define design factors for the carbothermal reduction process • Characterise the microstructure and chemical composition of the materials obtained and identify the materials of interest for the targeted applications; • Characterise and model the performance of the identified materials; • Carry out an economic study and a life cycle analysis of the most promising materials.
Bibliography	• 1. Sun, Luyi et Gong, Kecheng. Silicon-based materials from rice husks and their applications. Industrial & engineering chemistry research, 2001, vol. 40, no 25, p. 5861-5877. • 2. Schubert, P., Paganessi, J., Wilks, A., & Murray, M. (2012). Distributed Hydrogen Generation and Storage from Biomass. Materials Challenges in Alternative and Renewable Energy II, 105-14. • 3. Liu, N., Huo, K., McDowell, M. et al. Rice husks as a sustainable source of nanostructured silicon for high performance Li-ion battery anodes. Sci Rep 3, 1919 (2013). • 4. Marchal, Julien C., Krug III, David J., McDonnell, Patrick, et al. A low cost, low energy route to solar grade silicon from rice hull ash (RHA), a sustainable source. Green Chemistry, 2015, vol. 17, no 7, p. 3931-3940. • 5. Ahmad, W., bahrani, M., Yang, Z. et al. Extraction of nano-silicon with activated carbons simultaneously from rice husk and their synergistic catalytic effect in counter electrodes of dye-sensitized solar cells. Sci Rep 6, 39314 (2016). • 6. Chen, C. Y., Lin, C. I., et Chen, S. H. Kinetics of synthesis of silicon carbide by carbothermal reduction of silicon dioxide. British ceramic transactions, 2000, vol. 99, no 2, p. 57-62. • 7. Lee, Hyun-Cheol, Dhage, Sanjay, Akhtar, M. Shaheer, et al. A simulation study on the direct carbothermal reduction of SiO2 for Si metal. Current Applied Physics, 2010, vol. 10, no 2, p. S218-S221. • 8. Shatumbu T. Alweendo, Oluwagbenga T. Johnson, Mxolisi B. Shongwe, Frank P.L. Kavishe, Joseph O. Borode, Synthesis, Optimization and Characterization of Silicon Carbide (SiC) from Rice Husk, Procedia Manufacturing, Vol. 35, 2019, 962-967. • 9. Li, Xiaoke, Guangyong Zeng, and Xinyu Lei. "The stability, optical properties and solar-thermal conversion performance of SiC-MWCNTs hybrid nanofluids for the direct absorption solar collector (DASC) application." Solar Energy Materials and Solar Cells 206 (2020): 110323. • 10. Schubert, P.J., “System and method for controlling char in biomass reactors”, 3 Nov. 2011, US 20110266500

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Methodology and expected results	Methodology : • Literature survey of the parameters influencing the carbothermic reduction of SiO_2; • Study by thermogravimetric analysis of the pyrolysis and gasification of rice husk; • Study of the influence of pyrolysis and gasification parameters for the elaboration of SiO_2/C composites with controlled Si:C ratio; • Study by thermogravimetric analysis of the carbothermal reduction of SiO_2/C composites; • Definition of design factors of the carbothermal reduction process. Factors to consider might be (1) batch versus continuous operation; (2) seals and ports; (3) gas manifolds and pressure or vacuum requirements; (4) recover of solid materials and any post-processing which may be required; and (5) some consideration of power and control requirements. • Chemical (elemental analysis) and structural characterisation of the materials obtained (XRD, SEM, TEM, Raman); • Electrical characterisation (measurement of electrical conductivity/resistivity, carrier density (Hall effect), determination of carrier mobility, etc) • Study of the properties of use for the targeted applications in electronics and modelling; • Economic study and life cycle analysis of the most promising materials. Expected results : • Optimal conditions of synthesis of both SiC or Si-based materials from rice husk are defined and the influence of parameters is determined; • Proper design factors are defined in view of a practical implementation of the technology • The silicon-based materials are characterised from a chemical and microstructural point of view; • The properties of use for the targeted applications are studied and modelled; • An economic study of the production of the materials is carried out; • A life cycle analysis of the most promising materials is carried out.
Host laboratory	1. Laboratoire Energies Renouvelables et Efficacité Energétique (LabEREE), Institut International d'Ingénierie de l'Eau et de l'Environnement, Ouagadougou, Burkina Faso 2. Laboratoire sur l'Énergie Solaire, Université de Lomé, Lomé, Togo *With possible mobility to the Richard G. Lugar Center for Renewable Energy, Indiana University-Purdue University Indianapolis, Indiana, USA*
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Starting date	January 2nd, 2023
Duration	3 years + 1 year (on derogation)
Candidate profile	• Master of Materials science or solid-state physics or physical chemistry or equivalent; • Strong taste for experimentation and research; • Autonomous, dynamic, good interpersonal skills; • Fluency in English essential (minimum level required C1).
To apply	The application must include: • A letter of motivation; • A curriculum vitae; • A photocopy of the Master's degree or equivalent; • Photocopies of the Master's transcripts or equivalent; • The Master's thesis report. **Applications are made exclusively online at the following address:** **https://dev.2ie-edu.org/candidatures/formulaire/6** **The deadline for applications is December 7, 2022 at 3:00 p.m. GMT.** **No physical file or sent by email will be admissible.** **For any information contact: Mrs. Nadège Obi KAM** **Tel: (226) 25 49 28 00, Boxe 1531** **E-mail: nadege.kam@2ie-edu.org**