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Weblike chemical systems and their network topology in low-temperature reactive plasmas

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Chemical reactions in low-temperature plasmas for material processes are complex because such plasmas include molecule reactions leading to their resultant various radical species and enhance multiple parallel reactions via high-energy electrons. Previous studies reported to date handle their complexities with numerical calculations based on a corresponding set of the rate equations, but the calculation results frequently confuse us with unclear roles of several tens of species as well as unclear pathways of reactions. To uncover underlying processes in such complex reaction systems, a topological approach triggered by complex network science is one of the solutions for their clarification in various industrial reactors. In this report, we build up a network of chemical reactions in which nodes or vertexes are chemical species and edges are chemical reactions [1], and analyze it mainly on two different aspects. In a microscopic point of view, centrality indices of nodes developed in network science indicate roles of species (like as reactants, products, or intermediates) or their fractions for each role in an entire system [2]. In a macroscopic point of view, statistical properties of many networks in low-temperature plasmas show a scale-free-like topology that may imply robustness in the system stability. These facts indicate that a chemical system in low-temperature reactive plasmas substantially involve a kind of synthetic frameworks that are totally different from groups of elements collected randomly. [1] O. Sakai. K. Nobuto, S. Miyagi and K. Tachibana, AIP Adv. 5, 107140 (2015). [2] Y. Mizui, T. Kojima, S. Miyagi and O. Sakai, Symmetry 9, 309 (2017).