Microwave heating of materials: From polar liquid to metal oxides

Motohiko Tanaka, Motoyasu Sato, M.Suzuki, and M.Yamashiro

Coordination Research Center, National Institute for Fusion Science
322-6 Oroshi-cho, Toki 509-5292, Japan

Email: mtanaka@nifs.ac.jp

Energy efficient and environment-friendly heating and processing of materials have been made possible with the use of microwaves. Some materials are heated by absorbing the electric field energy of microwaves, and others by their magnetic field energy [1]. In series of our studies under the MEXT Tokutei Ryoiki Project [2], we are investigating the heating mechanisms of water (polar liquid) [3] and metallic oxide powders (solid). We have shown theoretically using molecular dynamics simulations that the heating mechanism certainly depends on materials: water is heated by electric field and metallic oxides by magnetic field. For the study of the former process, an explicit water model (Fig.1) is used, which has proven that water heating is due to rotational excitation of water molecules and irreversible energy transfer to translational energy by molecular collisions (Fig.2); crystal ice is not heated because of a strong hydrogen-bonded network. The latter heating can be explained by interactions between the microwave magnetic field and electronic spins of metallic atoms.

References:

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[2] "Science and Technology of Microwave-Induced, Thermally Non-Equilibrium Reaction Fields", Grant-in-Aid for Special Research Area from the Japan Ministry of Education, Science and Culture (FY2006-2010); http://phonon.nifs.ac.jp/

[3] M.Tanaka and M.Sato, Microwave heating of water, ice and saline solution: Molecular dynamics study, *Journal of Chemical Physics* 126 (2007) 034509.

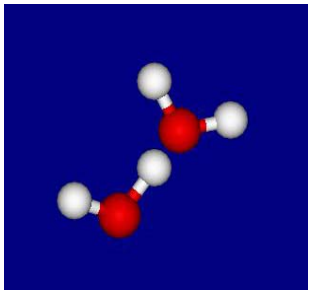

Fig.1 The simulation model of water molecules adopted in our molecular dynamics study. Adjacent molecules are virtually chained by strong hydrogen bonds between hydrogen and oxygen atoms, under which molecules interact with the microwave electric field.

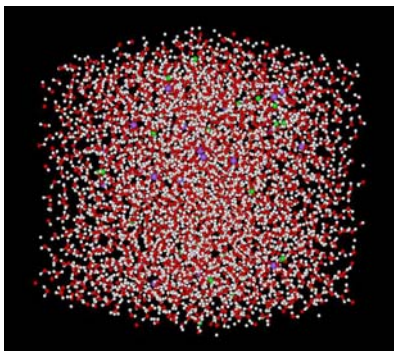

Fig.2 Bird's-eye view of microwave heated water containing $(14)^3$ water molecules of Fig.1. Na and Cl salt ions are also contained. In salt water, Joule heating of salt ions is predominant over ordinary dipole heating of water. Because of applied microwave and finite temperature, the ordered structure of ice is almost lost in a mesoscopic scale (> 10 Angstroms) [3].