§16. Mechanism of Processing by Irradiation of Monochromatic Coherent Electromagnetic Waves

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1.Introduction

In more than 20 years, huge numbers of studies have been explored to make clear the mechanism of unexpected behaviors in microwave processing, for examples, the crystallographic transitions from microns to several tens nano meters on magnetic materials involving unpaired spin in 3d orbit under the exposure in magnetic field of microwave the rapid sintering of many kind of ceramics without crystal growths and the synthesis of natural super-lattice structure in the binary system , etc.

The ultrasound excitations by microwaves had been studied actively in the condensed matter physics in the ages of 1950's to 1970's. However, most of the works were done in the temperature regimes lower than 100 °K, as the kinetic energy of coherent phonons were much lower than the thermal phones at higher temperatures. B. C. Towe reported that "the reported physical changes in certain materials resulting from their low-thermal exposure to intense GHz microwave radiation might be explained through generation of electromagnetically induced ultra high frequency ultrasound (hypersonic) waves within their structure and that it can be shown from laws of electromagnetism that microwave fields should produce mechanical forces within dielectric, ferromagnetic, piezoelectric, and semiconductive materials and so give rise to high frequency acoustic vibrations" .

The striking similarity of ultrasound and microwave at high temperature remained us the word of "**coherency**". The Gibbs free energy (G = H – TS) contains two different ordering terms of the disordered thermal motions (origin of high entropy) and the coherent kinetic motions and microscopic ordered structure (origin of low entropy). As far as the microwave processing uses monochromatic frequency, the electric or magnetic fields generate ordered motions in the material on the first step. The entropy of coherent phonons is lower than the random motion of thermal photons. H.D. Kimrey reported that the activation energy from the relation of sintering rate for alumina to reciprocal temperature showed a drop in activation energy from 575kJ/mol to 170 kJ/mol for microwave sintering. The decreasing of activation energy has been observed in the reduction process of Titanium oxide (TiO_2) under the irradiation of microwave magnetic field. The fall of energy can also be seen on the phase transitions. For example, the nano-crystallographic of ferromagnetic powders in which the hard magnetism converted to very soft one. These experiments show that the microwave couples with different energy path on the phase transitions.
These phenomena require very sophisticated studies of renormalization theories, molecular dynamics, etc. on the bases of ab initio calculation.

The theoretical researchs are going to answers; " how to excite the collective motion in solid material by such monochromatic electromagnetic wave? " and " What is the mechanism to mitigate a driving microwave to a wide frequency spectrum of the blackbody radiation? ".