1. Outline of Research

I have researched MFE on chemical, physical and biological phenomena.

MFE on chemical phenomena

MFE on photochemical reaction

MFE on photochemical reaction in micellar solution

Photochemical reaction of p-xyloquinone was studied in a micellar solution [3]. The excited triplet p-xyloquinone abstracts a hydrogen atom from a sodium dodecyl sulfate (SDS) surfactant molecule in the SDS micelle, thereby forming a triplet pair composed of the p-xylosemiquinone radical and SDS-derived radical. By application of a 0.095 T field, the transient absorption intensity of the pair increases considerably. The result is interpreted in terms of the radical pair mechanism. Similar MFE were observed in many photoreactions of carbonyl compounds in micellar solution [5, 7, 13].

The photochemical hydrogen abstraction reaction of xanthone (XO) from xanthenes (XH) in SDS micellar solution was examined [6,11,12]. This photoreaction exhibits remarkable MFE in terms of degradation yield of XO, product yield, and lifetime of transient species. By applying a 0.08 T field, the triplet–singlet intersystem crossing rate decreased significantly. The results are interpreted by the radical pair mechanism.

MFE on the photochemical reaction of bifunctional chain-linked molecules

The distance of two radicals in a radical pair is known to serve a key role in the onset of MFE because an intersystem crossing of radical pair occurs when a singlet and triplet become nearly degenerate in energy. However, the distance at which this occurs has not been verified experimentally. To clarify the role of the distance, MFE on the photoreaction of bifunctional chain-linked molecules, which have a hydrogen donor molecule at one end and a hydrogen acceptor molecule at another end, were studied in homogeneous solution [21, 24]. As expected, the magnitude of MFE depends strongly on the chain length. Marked MFE is apparent when the mean distance becomes about 1–1.5 nm. Similar results were obtained from the photoreaction of many other bifuctional chain-linked compounds [20, 23, 27, 44].

Effect of a high magnetic field (<14 T) on photochemical reaction

A high magnetic field (<14 T) affects the lifetime of a biradical generated from an α-cyclodextrin inclusion complex of a phenothiazine-viologen chain-linked compound [43]. It exhibits interesting field dependence. In a low field (< 1 T), the lifetime increases steeply, although it decreases gradually in a high field (> 1 T). The high field effect is explained in terms of anisotropic g and hfi-induced relaxation in the radical pair mechanism.

MFE on electrochemical reaction

MFE (< 2 T) on electrochemical reaction

We examined electrochemical reactions because the formation of the radical pair was expected to generate radical pairs on electrodes. In an anodic oxidation of gold, we found an unusual phenomenon: The anode surface covered by black thin oxidized film at a zero field was dissolved by application of a 1.7 T magnetic field [68]. The result is explained in terms of Lorentz force, which induces convection of the electrolyte solution near the anode surface.

MFE on thermal reaction

MFE (<15 T) on metal dendrite formation

MFE (horizontal, < 8 T) on silver and copper dendrite deposition on filter paper was examined [74-78]. The dendrite patterns are affected strongly by the magnetic field. The results were interpreted in terms of magnetic force. The force induces convection of the solution on the paper. The silver dendrite formation reaction was investigated further using a vertical magnetic field (< 15 T). It was observed that the dendrite grows by accompanying the processional motion of the growing top in the magnetic field.

Magnetic induction of morphological chirality (<15 T, <1500 T^2/m)

We studied MFE on the silicate garden (chemical garden) reaction and showed that the three-dimensional morphological chirality of formed membrane tube can be controlled by a magnetic field [82, 83, 88]. The result is explainable in terms of Lorentz force-induced convection, the direction of which is controlled by the field direction and boundary conditions, such as those at the vessel wall (See “Introduction”).

MFE (<15 T) on oscillation phenomena

We studied MFE on oscillation phenomena. The oscillation period of the salt-water oscillator is controlled by application of a vertical magnetic field [133].

The propagation speed of the reaction front in Belousov–Zhabotinsky reaction was affected by an MF [89, 90]. These results are explained in terms of the magnetic force. MFE on the cathodic potential oscillation of zinc electrode is explainable by the Lorentz force-induced convection [72].

MFE study using permanent magnet

Currently we are interested in the effects of a weak magnetic field produced by permanent magnets (< 0.5 T) because we can use MF easily. We studied MFE on the photosensitized oxidation of DPBF in micellar solution (see “Introduction”). It is useful for clarifying photochemical reaction pathways and for chemical demonstration of MFE etc. (see “Introduction”). Utilization of magnetic fields in research is expected to become popular in the near future.

MFE on physical phenomena

MFE (< 8 T) on crystal growth

MFE on the crystallization of benzophenone, naphthalene, and other organic compounds from their solution were examined [92-96]. They oriented in a magnetic field. The results are explained in terms of magnetic anisotropy of crystals. Results also suggested that the relation of the field direction and earth gravity are sometimes important for magnetic orientation.

As a natural extension, MFE on multi-wall carbon nanotube (about 50 nm diameter and 1–5 μm long on average) was also examined [99]. Scanning electron microscopy revealed that it is oriented with the tube axis parallel to the magnetic field. From the Boltzmann distribution of tube directions, magnetic anisotropy of the tube is estimated. Results show that MF is useful for the alignment of nanoscale materials (see “Introduction”).

MFE (< 15 T, 1500 T^2/m) on crystal growth

We studied the influence of magnetically simulated microgravity on *lysozyme* crystal growth to verify it experimentally [107]. The crystallographic quality of *lysozyme* crystal is improved by the simulated microgravity. Results demonstrate the usefulness of the magnetic field.

MFE (<15 T, 1500 T^2/m) on surface phenomena of water

Water is a key material for life on earth. We have studied MFE on surface phenomena of water [122,124]. Preparation of a thin water film of large size (30 mm diameter), which cannot be prepared on Earth, can be done using magnetic levitation conditions. This study develops methods for the preparation of a new functional thin film, vinyl alcohol film doped with oriented carbon nanotubes, which cannot be prepared on Earth [125,127].

MFE (<15 T, <1500 T^2/m) on solution convection

Photoinduced thermal convection of a benzene solution of diphenylamine and carbon tetra bromide was examined [113]. A colored compound is formed during UV pulse laser irradiation. By applying a -1200 T^2/m field, the thermal convection is enhanced, although it is suppressed by application of a +1000 T^2/m field. The result is interpreted in terms of magnetic force acting between the bulk solution and colored solution.

Magnetic levitation of plastic chips

Magnetic levitation of plastic chips was studied [111]. Their diamagnetic susceptibilities were obtained from the magnetic force field (BdB/dz) necessary for levitation. Results demonstrated that they can be separated by the difference in levitation height. Magnetic levitation is a useful technique for magnetic susceptibility measurements of plastic chips as well as separation.

MFE on biological phenomena

MFEs (< 9 T) on microorganism movement

MFEs on the movement of microorganism were studied (see “Introduction.”). *Euglena gracilis Z* broadens uniformly in a Petri dish at a zero field [139, 140]. By application of inhomogeneous 8 T field living *Euglena* moves to a higher field, whereas the dead one moves to a low field. This behavior was interpreted in terms of magnetic orientation of *Euglena*. Effects of a high horizontal magnetic field (8T, 400 T^2/m) on *E. coli* movement were examined [142]. The speeds for movement from a high field to a low field and for the opposite movement were 1.35 and 0.49 cm/h, respectively, but they were 0.65 cm/h at a zero field. These results are explainable in terms of magnetic force. Effects of horizontal strong MF on the swimming behavior of *Paramecium caudatum* were studied [145]. In an 8 T field, *P. caudatum* swims parallel to the magnetic field, but in a zero field it swims randomly. Magnetic orientation is inferred as the cause of the behavior in a magnetic field.

MFE (<15 T, < 1500 T^2/m) on Amphibian Development

Effects of a strong vertical magnetic field on *Xenopus laevis* were examined [143]. A strong MF markedly retarded normal development and induced microcephaly, two heads, abnormal cement glands, and multiple malformations, indicating that MF inhibits normal embryonic development.