Development of heating element and techniques for detecting its temperature and position for hyperthermia

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Magnetic hyperthermia is a promising cancer therapy gaining great interest in recent years with less invasive than surgical therapy and fewer side effects compared to chemotherapy. This therapy induces cell death within the therapeutic temperature range of 40–45°C utilizing heat generation from magnetic particles injected into tumor subjected to a high frequency magnetic field. To make this therapy feasible in clinical settings, in addition to the magnetic particles, important elements include techniques for detecting the temperature and position of magnetic particles in determining the effectiveness of therapeutic heating. Among heating elements, nanoparticles have been gaining more attention due to their potential as diagnostic and therapeutic agents. Besides, self-controlled heating elements with low Curie point have been studied due to the fact that they are capable of avoiding overheating and damaging of the surrounding healthy tissue. In previous studies[1-2], we developed thermosensitive magnetic micro/nanoparticles with high heating efficiency for tumor treatment and considerable permeability change around Curie point for temperature and position monitoring by using the nanoparticles to fill the gaps between microsize ferromagnetic implants with low Curie temperature (FILCT) (Fig. 1). Thereafter, by utilizing the permeability of FILCT that varies around its Curie point resulting in the change in the magnetic field around it, we also developed a wireless temperature measurement method to monitor the temperature of treated areas using pickup coils (Fig. 1).
Currently, noninvasive methods for sensing the magnetic particles in vivo are magnetic resonance imaging, positron emission tomography, and magnetic particle imaging. However, they are either costly, complex, time-consuming, requires expertise or a combination of these disadvantages. Taking the advantage of the fact that the induced voltage in pickup coil depends on the position of magnetic particles, we also developed a simple, rapid, low cost and automated localization system using three pickup coils symmetrically installed inside drive coil[3]. To localize the implant, the magnetic field supply and detection unit of drive coil and pickup coils is coarsely scanned over the whole existence possibility area of the implant and then moved to a position close to the implant until there is no difference in pickup voltages (Fig. 1). Using the developed system, the implant could be automatically localized with accuracy below 1 mm. Future studies are needed to extend the detectable distance for deeper tumor by investigating the optimal micro/nanoparticles and pickup coil as well as investigate in vivo how distribution of the implant in affected part affects the accuracy of the proposed method.

References
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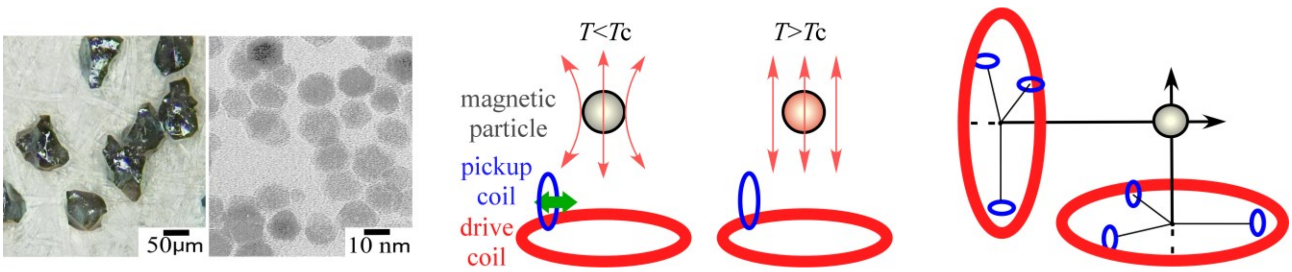

Fig. 1 Heating elements (microsize ferromagnetic implant with low Curie temperature and magnetite nanoparticles) (left), the concepts of wireless temperature measurement method (middle) and localization method (right) for the implant using the voltages induced in pickup coils around its Curie point.