3D MRI of solids

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Description:

Magnetic resonance (MR) imaging of soft tissues, using the proton (1H) signal from liquid water, has emerged as one of the most important medical imaging modalities. However, MR imaging of solids, such as bone, has not achieved biomedical significance because the short spin-spin relaxation times of nuclei in solids results in broad line-widths and poor spatial resolution. The prospect of extending the reach of MR imaging to the study of solids could transform the role of MR measurement in biomedical research and could have broad application in industrial and clinical settings.

Yale investigators have developed a novel technique that makes MR imaging of solids possible through greatly improved resolution in solid state MR. Their fundamental discovery exploits the internal structure of pulses to control spins, rather than assuming instantaneous pulses as is the current practice. This opens many new ways of controlling and measuring spin systems, allowing for significant improvements and advances in MR imaging and also MR spectroscopy of solids and semi-solids. The current version of the method may be used on any spin-1/2 isotope that can be used for NMR analysis (e.g. 1H, 13C, 15N, 29Si, 31P).

Fields of Application:

1. MRI of solids complements X-ray in non-destructive applications that require study of the interior of opaque solids. For example, bone imaging by this method provides mass densities of bone mineral and matrix density without ionizing radiation, and is sensitive to chemical composition and structure. The method can be implemented with current pulse-generating machinery. As a result, after tailoring to specific applications, significant improvements can be gained at relatively low cost.

2. Novel echoes have been demonstrated with this method, which could provide contrast (liquid/solid ratio) or other important information about a sample in the study of biomaterials, solids in liquids, and soft materials (bones/teeth/polymer solid composites).

3. The method can be combined with MR spectroscopy to obtain highly specific data on chemical composition and structure, detecting the presence of an element, labeled compound, binding state or complex.

4. Clinically relevant applications are human bone biopsy, 3D imaging of medical pathology samples, which will allow planning of optimal 2D sectioning, and imaging for fundamental biomedical research.

5. The method allows 3D measurement of complex magnetic field profiles inside solids. For example imaging of ‘through-silicon vias (TSVs)’ in 3D chip architectures: unlike other methods
that diagnose TSV faults, here the nuclei close to a TSV, deep inside a 3D chip stack, serve as the ‘field sensors’.

A novel form of MRI applied to opaque solids like (A) rabbit bone can reveal the (C,D) internal structure, complementing (B) micro-computer-aided tomography imaging.

Publications:


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