A Pyrolytic Graphite Foam for Magnetic Susceptibility Matching to Human Tissue

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Introduction: Field gradients near air-tissue susceptibility interfaces can lead to artifacts including poor fat suppression, image shifts, blurring, or dropouts. External water bags can remove the susceptibility gradient from the imaging volume, but these are heavy and are incompatible with embedded RF coils. Here we introduce a pyrolytic graphite foam that matches human tissue susceptibility, and is ten times less dense than water, and is compatible with embedded RF coils.

Theory: Pyrolytic graphite (PG) is an anisotropic crystal with –595 ppm susceptibility across plane and –9 ppm through plane [1]. Others have carefully shaped a solid PG insert for shimming of the air sinuses [2,3]. We calculated that a *randomly oriented* distribution of PG powder with volume fraction f in air (or dispersed uniformly in a foam) has bulk susceptibility = $(-298f + 0.36)$ ppm. Moreover, this bulk susceptibility is *isotropic*. Hence, to match human tissue of –9 ppm, we must pick f = 0.031. The dilution tolerance is not stringent; 10% accuracy guarantees better than 1 ppm susceptibility matching. A Green's function analysis predicts that the field inside the patient will "blur out" PG density variations, so the PG particle size need not be smaller than about 250 micron.

Methods: Solid PG (scitoys.com) was ground to approximately 250-micron-diameter flakes and mixed with volume fraction f =0.031 thoroughly into polyurethane foam (TAP X-30) while the foam set. A phantom was created with three air-tight plastic jars oriented perpendicular to the B0 field, and immersed in a right cylinder filled with water. One jar was filled with the PG-foam (see Fig. 1 below), one with air, and one with water. Off-resonance field plots were obtained on a 1.5T GE Signa scanner by taking the phase difference between two GRE images with a change of TE = 2 ms.

Results: Figure 2 shows the off-resonance image of the three jars in water. Note the classic dipole field outside the air-filled jar, as expected. The PG foam composite has excellent susceptibility matching, comparable with the water-filled jar. There are small, local field variations close to the jar, due to local variations in PG flake density, also as expected.

Discussion: The PG foam may be formed as a wrap, or as a filler material in a conformable bag, or within a rigid expanded polystyrene matrix, depending on convenience. PG-foam pads may be useful for MRI near the foot, hands, chin, breast, neck, shoulder, head, and knee. PG foam ear plugs and patient pads may also be useful. For embedded RF coils, we expect the PG foam should have negligible bulk conductivity.

Conclusion: This proof-of-concept experiment was successful. Because the foam can be ten times less dense than water, it is practical to use a foam large enough to ensure excellent field homogeneity. It is possible to embed RF coils within the foam, unlike with water matching. This allows for phased array and SENSE acquisition schemes. PG foams could significantly improve the robustness of MRI near the skin, especially for high field MRI, b-SSFP, and spectroscopy.

References:

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Figure 1. Jar of PG-foam with bulk susceptibility matched to human tissue.

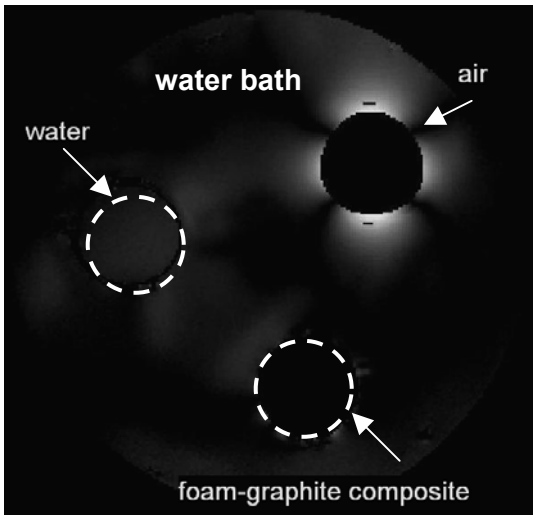

Figure 2. Off-resonance coronal map of water, air, and PG-foam jars (outlined with dashed circles) in water. The PG foam shows excellent matching with the water, as desired.