

Development of a Human Breast Tissue Phantom for Optical Coherence Tomography Imaging

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Introduction

Breast cancer is the second leading cause of cancer death in women, after lung cancer. One in eight women either has or will develop cancer in her lifetime. Advances in diagnostic techniques and treatments during the past decade have decreased death rates for breast cancer by 20%. Diagnosis of breast cancer depends on the ability to distinguish changes in breast tissue properties such as mechanical properties and optical absorption. MRI, X-ray mammography, and ultrasonography are the most common imaging techniques that are currently used in breast cancer diagnosis. Optical coherence tomography (OCT) is an imaging technique that transcends certain limitations such as low resolution, low contrast, and low sensitivity that are imposed by conventional imaging techniques and can potentially be combined with other imaging modalities to produce a new way to accurately detect breast cancer tumors. Phantoms with tissue like properties are used as substitutes for real tissue to test system design and evaluate optical techniques. A phantom with the same optical properties of breast tissue has been developed to assess the ability of OCT to accurately detect cancer tumors in breast tissues.

Techniques/Approach

Phantoms are constructed to model the transport of visible and near infrared light in tissue. They are mainly composed of a scattering medium, an absorbing medium, a diluent, and in some cases fluorophores. Tissue phantoms should satisfy the following requirements:

- ❖ Components must be compatible regarding chemical stability
- ❖ Phantom should have the same optical parameters as the tissue of interest
- ❖ Phantom sample should be stable and independent of environmental influence
- ❖ Sample preparation should be simple, quick, and safe
- ❖ Index of refraction should be close to that of tissue which is ~ 1.4

Table 1. Optical properties of breast tissue at 850 nm

Type of Tissue	Absorption Coefficient (cm ⁻¹)
Normal	0.038
Carcinoma	0.40

Table 2. Phantom matrix materials used to hold absorbers and scatterers

Phantom Matrix Material	Solid/Liquid/Flexible	Organic chemical compatible	Index of refraction
Aqueous suspension	L	Y	1.34
Gelatin/agar matrix	F	Y	1.35
Polyacrylamide gel	F	N	1.35
Polyester or epoxy resin	S	N	1.54
Polyurethane resin	S	N	1.50
RTV silicone	F	N	1.4

Table 3. Scattering material used in phantoms

Scattering material	Permanent	Organic compatibility	Index of refraction
Lipids	N	Y	1.45
Polymer microspheres	Y	Y	1.59
Ti O ₂ / Al ₂ O ₃ powders	Y	Y	2.4 to 2.9

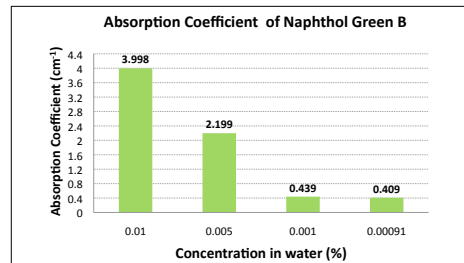
Whole blood, Ink, or molecular dyes or a combination of these substances are usually used as absorbing materials.

Results

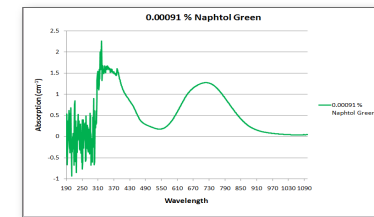
The following materials were selected for the construction of the normal phantom due to their organic compatibility and their refractive indices that are close to that of tissue:

- ❖ Water (500 ml)
- ❖ Milk 2% fat (100 ml)
- ❖ Gelatin (105 grams)

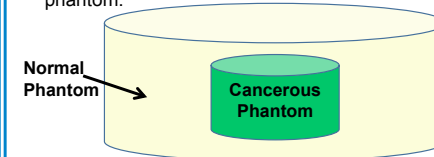
Cancerous tissues are known to have higher absorption coefficients due to their higher blood content. Naphthol Green B was used as an absorbing agent to make the cancerous breast phantom. The scattering of normal and abnormal phantom was assumed to be the same. The absorption coefficient of different concentrations of Naphthol Green B were measured with a spectrophotometer.



Absorption Spectrum of 0.00091% Naphthol Green B in water:



0.00091% Naphthol Green B was added to the normal phantom ingredients to obtain the cancerous phantom.



Conclusion

Breast tissue phantoms with the same absorption coefficient of cancerous and normal breast tissue were developed for the purpose of OCT imaging. Different optical properties for the phantom can be achieved by varying the concentrations of scattering and absorbing materials and verified by integrating sphere measurements. The phantoms developed in this project can be used in future experiments for OCT imaging.

References:

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