Characterizing novel phantom materials for biomedical applications of electrical impedance tomography

Anjali Sehrawat[1], Barry Belmont[1], Simon Ghionea[1], and Matthew D Keller[1]

[1]Global Health Labs, Inc, Bellevue, Washington, United States of America, anjali.sehrawat@ghlabs.org

Abstract: EIT phantom materials with tuned conductivity were developed using several base resins, carbon black, and graphite. Material conductivity was characterized with a tetrapolar probe across a frequency range of 1-200 kHz. Measured conductivities ranged from 5.28 mS/m to 3.29 S/m at 100kHz, matching a range of biological tissues.

1 Introduction

Critical to successful biomedical electrical impedance tomography (EIT) implementation is experimental verification using phantom models that reflect real-life cases, both in terms of passive electrical properties (e.g., conductivity) and accurate geometric representation. Unique geometries can be achieved by using solid materials that are mechanically and electrically stable, castable and/or machinable. Various studies have explored developing novel materials [1, 2], where the reported conductivity is limited to the study's EIT requirements.

The objective of this study is to create materials with tuneable conductivity that match various biological tissues, while primarily focusing on amniotic fluid conductivity, reported to be approximately 1.27 S/m for frequencies <1 MHz [3]. This study is part of a larger effort to develop a geometrically accurate pregnant patient torso with a uterine phantom model to assess EIT-based reconstruction of the uterine volume.

2 Methods

2.1 Material composition

Two-part castable epoxy and polyurethane were selected as base resins for phantom materials—Smooth-On EpoxAcast™ 690 and VytaFlex™ 20, respectively. Various conductivities were achieved by adjusting the percent by weight carbon black (Alfa Aesar, acetylene, 50% compressed, 99.9+%) and graphite (Fischer Chemical), summarized in Table 1. Samples were created by slowly adding carbon black and/or graphite powders into the resin mixture while manually stirring until a homogenous mixture was achieved. For more viscous mixtures, a paint drill mixer was used at a low speed. After the material was cast and cured, two-inch diameter samples were cut, roughly one inch in thickness for measurement.

Table 1. Phantom material composition summary.

Base Resin	Carbon Black (% w/w)	Graphite (% w/w)
EpoxAcast / VytaFlex 20	3	-
EpoxAcast / VytaFlex 20	5	-
EpoxAcast	10	-
EpoxAcast / VytaFlex 20	5	30
EpoxAcast / VytaFlex 20	3	40

2.2 Tetrapolar probe construction

A custom tetrapolar probe was designed and built to characterize material conductivity, shown in Figure 1. The probe consists of four 0.02" diameter platinum wires spaced 5mm apart, housed in a PEEK block. Sample measurements were taken using a LCR meter (Hioki IM3536). Contact between samples and probe was facilitated using a small droplet of ionic solution (1 M KCl, ~11 S/m) at each platinum wire tip. The probe was randomly oriented on the surface of a sample for five individual measurements, each comprising of 10 frequency sweeps (1-200 kHz).

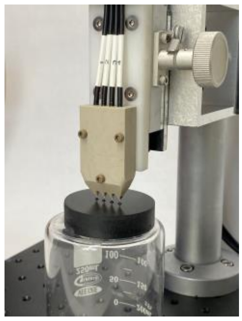

Figure 1: Platinum wire tetrapolar probe testing a sample.

3 Results and Conclusions

This study demonstrates the development of phantom materials that can be used for various biomedical EIT applications. Figure 2 displays the mean conductivity of each material investigated across the 1-200 kHz range. EpoxAcast with 5% carbon black (1.25 S/m at 100kHz) best matched the target amniotic fluid conductivity. Follow-on work will aim to increase material methods-related homogeneity before using it to cast realistic anatomical models for EIT experimentation.

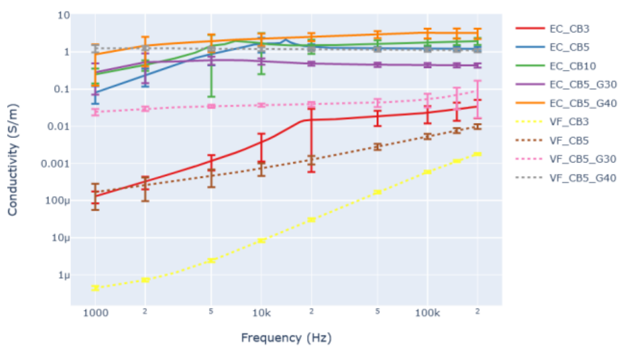

Figure 2: Mean material conductivity and standard deviation over 1-200 kHz for EpoxAcast (EC) and VytaFlex (VC) compositions listed in Table 1.

References

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