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Repository of materials mimicking dielectric properties of biological tissues

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Abstract

Anatomical phantoms with Tissue Mimicking Materials (TMMs) representing the properties of biological tissues, such as dielectric properties, are essential for validation of electromagnetic (EM) medical devices. In this paper, we present an open-access repository of TMMs that aims to collect and summarise ingredients and recipes of TMMs used for these applications. This repository allows to avoid duplicated efforts while creating TMMs and to accelerate the development of EM medical devices.

1 Introduction

Electromagnetic (EM) medical devices have been developed for distinct medical applications, from cancer detection [1] or staging [2], disease assessment [3, 4, 5], cancer thermal treatment [6], non-thermal treatment of benign conditions [7] or treatment monitoring [8]. Independently of the application, one aspect that is common to the development of EM devices is the validation of the technology with physical anatomically realistic phantoms of the body part under examination with a true representation of the tissue properties. The essential properties for this purpose often include dielectric properties, which define how the tissues interact with an electromagnetic field. Thus, many Tissue Mimicking Materials (TMMs) have been proposed to mimic biological tissues.

Body physical phantoms for EM devices validation can be divided into two major groups: compartment or solid phantoms. The choice of one of the groups depends on the anatomical complexity needed for the phantoms, the reliability of the properties of TMMs and mechanical longevity of the phantoms. Compartment phantoms comprise shells delimiting the different tissue cavities, allowing for more complex shapes, and are usually filled with liquid TMMs. State-of-the-art recipes of liquid TMMs include mixtures of Triton X-100 (TX-100) surfactant, water and salt [9]; glycerin or canola oil and water [10]. Concerns on using liquid TMMs include the instability due to water evaporation if not carefully conserved, and the effects of plastic shells of compartment phantoms. Solid phantoms are made of semi-solid or solid TMMs where each tissue is represented by a different solid mixture. Recipes of semi-solid or solid TMMs include: TX151, polythene powder and water [11]; gelatin and oil [12]; carbon-black, graphite and polyurethane [13]. Limitations of solid TMMs encompass instability due to water evaporation, leaching of ingredients between adjacent mixtures, shape deterioration or heterogeneity issues.

Considering the extensive number of recipes and ingredients for mimicking distinct biological tissues, there is a need of a tool that can facilitate the search for TMMs. Recently, we developed an open-access repository of dielectric and thermal properties of biological tissues [14] under the framework of MyWAVE COST Action. Following this work and by several requests of the research community, in this paper we present a novel repository of TMMs. In the following sections, we present the features of the repository and explain how researchers can benefit from and contribute to it.

2 Repository

The open-access data repository of TMMs was created and is hosted in MyWAVE COST Action's website [15], together with the previously developed repository of dielectric and thermal properties [14, 16]. The repository was developed in line with the FAIR (Findability, Accessibility, Interoperability, and Reusability) principles, allowing researchers to search, upload and download information about TMMs.

The data repository includes TMMs metadata and allows the addition of measurement data. As of now, it contains 12 TMMs recipes. The repository will be populated with state-of-the-art recipes and researchers will be invited to upload their own recipes. Other researchers can proactively register in the website and upload their data after having their account validated. The user area is common to the repository of dielectric and thermal properties, so users can upload data to both repositories with the same account. Regular visitors can access the repository and search the TMMs (Fig. 1). The search page shows all approved TMMs with filtering options by metadata (detailed in the next section). TMMs are listed with information of the corresponding

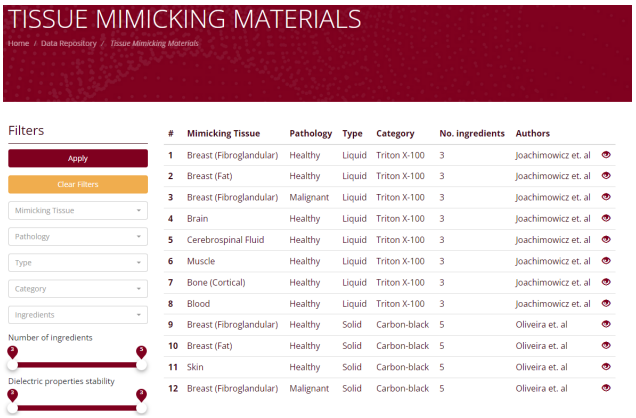

Figure 1. Search page of TMMs repository, including some example entries and filters.

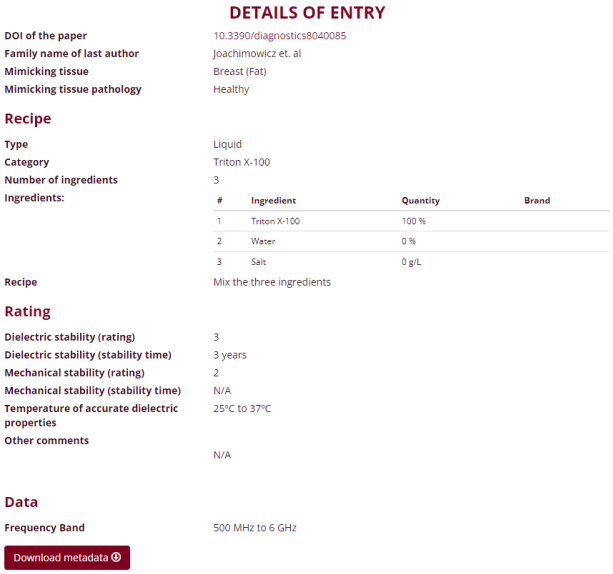

Figure 2. Example of details page of TMMs.

mimicking tissue, its pathology, type of TMM, category, number of ingredients and the authors of the recipe. The details of each TMM can then be explored in a different page (Fig. 2). CSV files can be downloaded with the existing data (metadata or measurement data).

2.1 Metadata

The metadata are related to the recipe of the TMM, as shown in Fig. 3. The requested metadata include: mimicking tissue and its pathology information (healthy, benign or malignant); type of TMM (liquid, semi-solid or solid); category of TMM (gelatin, TX-100, carbon-black or other); number of ingredients; details of ingredients (name, quantity and brand); recipe instructions; dielectric properties stability (rating and time); mechanical properties stability (rating and time); range of temperatures in which the properties are accurate. These metadata are used as filtering options in the search page. An additional section for comments is available, where users can write, for example, about how

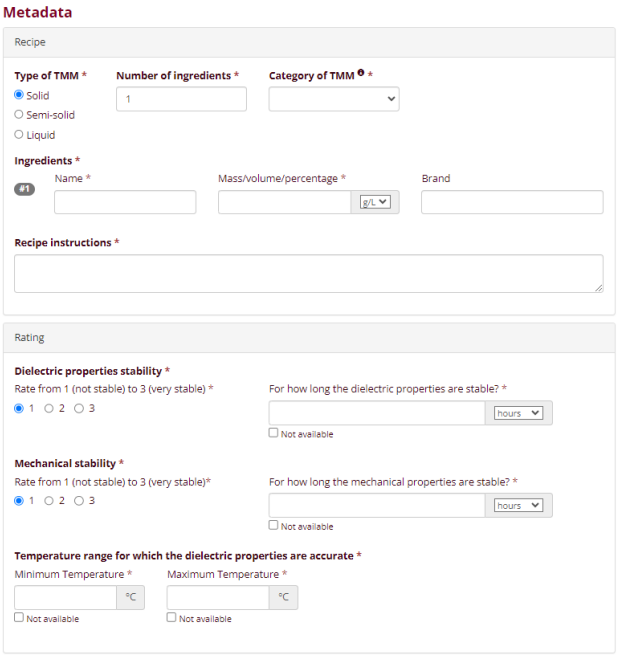

Figure 3. Upload form of metadata of TMMs.

they measured properties stability or mention other relevant properties analysed.

Although the rating of dielectric and mechanical properties stability can be subjective, it will allow a more direct comparison between mixtures, providing a more informed decision when choosing TMMs.

When uploading, the authors can also assign to their submission the family name of the first author and the DOI of the paper where the TMMs were presented.

2.2 Data

Dielectric property data can be uploaded in raw form (by uploading a .CSV file), or as Debye or Cole-Cole models. Although users are encouraged to do so, the registered users can also choose not to upload the data, and upload only the metadata and provide the paper where the details are published. Nonetheless, the frequency band in which the measurements are valid is required, as this will be one of the filtering options in the search page.

3 Conclusion

This paper presents a data repository of TMMs that can be found at https://www.um.edu.mt/projects/mywave/data-repository/tmms/. The repository aims to facilitate the validation of EM medical devices, by providing a compilation of materials in a systematic way that can be used to mimic several biological tissues. Ultimately, it may allow to avoid duplicated efforts in creation of TMMs and accelerate the development of EM medical devices.

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