i9MASKS

How can we make breathable PDMS?

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Introduction

Coronavirus is a severe pathogen that primarily targets the human respiratory system, being mostly transmitted via person-to-person [1]. This transmission occurs mainly via direct contact or through droplets spread by speaking, coughing or sneezing from an infected individual [1]. Face masks are a type of personal protective equipment (PPE) which plays a crucial role in reducing virus transmission, by preventing the spread of respiratory infections when social distancing is not possible [2]. Regardless the advantages in the use of PPE to prevent the spread of COVID-19, wearing a mask cover in a daily basis, brings many challenges and discomfort. In general, a traditional face mask covers a major part of the human face, which can crucially affect social interaction, once our faces provide the key information of personal identity [3]. Besides that, the process of using a mask, impairs people's communicative ability, because the masks limit lip-reading, and muffles the vocal sound. Hence, reducing the effectiveness of auditory information that is received. The health sector is one of the most affected, since communication between patient and clinician is at the heart of medical care [3]. In this regard, **the main goal of the i9MASKS project is to improve our lives and our communication with others, by creating a transparent and breathable face mask**. To this end, this project was based on the use of PDMS for the manufacture of masks, a transparent and biocompatible material, ideal for being in contact with the skin without causing allergies, providing the necessary transparency for people to recognize each other and to communicate. This approach is extremely favorable for the contact between healthcare professionals, between the healthcare professional and patients, between people, and special favorable for the voiceless and deaf people who resort to lip reading.

However, during the development of the project i9MASKS some issues were detected in the fabrication of the masks, namely (i) the condensation inside the mask that leads to the loss of transparency and (ii) how to make the mask breathable without losing protection for COVID-19. Therefore, **the objective of our work was to create pores in the PDMS mask** that allow air to pass through, so that the **mask is breathable but preventing the virus**. To this end, **various approaches were studied in order to create ideal sized pores**.

Materials and methods

PDMS FABRICATION

In this work 3 strategies were tested to create porous PDMS. In a first method different conditions such as reagents, water and temperatures were tested. In a second, sugar was used and a third using different concentrations of SDS in Di water.

Table 1: Methods used to create porous in PDMS fabrication

Method	Reagent	Ratio of PDMS oligomer: crosslinker	Ratio PDMS oligomer: reagent: water	Ratio PDMS: reagent	Final cured temperature	Observation
1	Diluent Solvent White Petroleum Petroleum ether Trichloromethane	10:1	10:3:1	10:3	80ºC RT	Pre-warmed solution for 10 minutes at 120ºC before added the crosslinker
2	Sugar	10:1	—	4:1 6:1	80ºC	Ultrasonic bath used to dissolve cured PDMS
3	1% SDS in DI Water	10:1	—	Mass percentage: 1,5,8 and 10%	80ºC	The mixture was manually blended until a uniform emulsion (milky and opaque) was achieved.

PDMS PERMEABILITY TEST

In order to determine the breathability of the samples produced, tests were carried out to determine air permeability with the FX 3300 Air Permeability tester III from TEXTEST INSTRUMENTS. The tests were carried out according to the Portuguese standard NP ISO 9237: 1995. The sample area was 20 cm^2 and the pressure used was 200 Pa, since the PDMS fits the non-woven type.

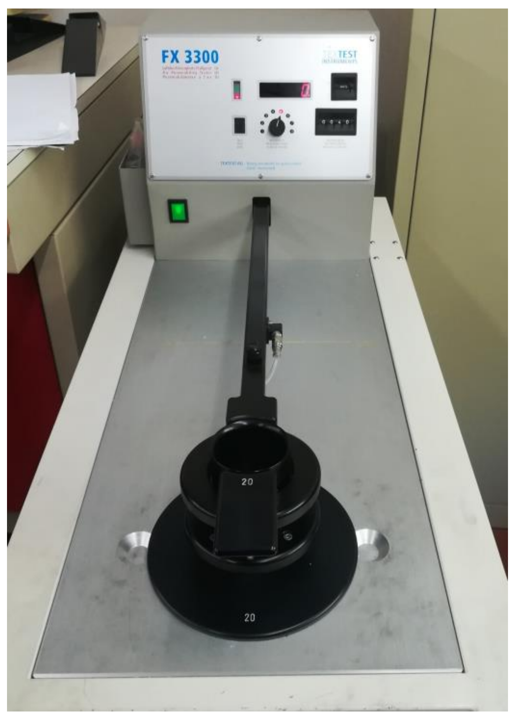

Figure 1: FX 3300 AIR PERMEABILITY tester III

Results and Discussion

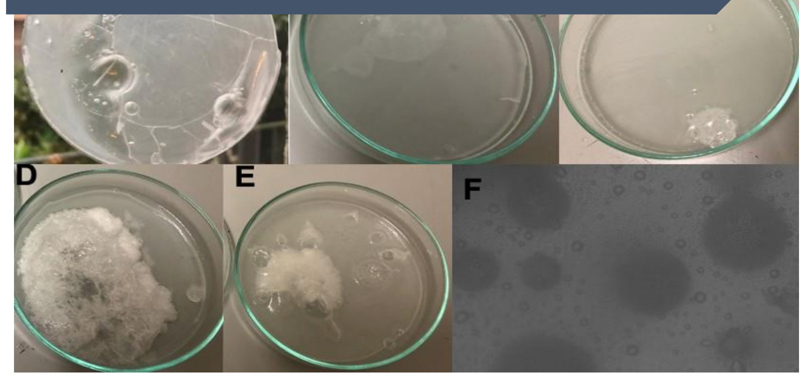

Figure 2. Samples cured at 120ºC **A**: Sample Diluent **B**: Sample Solvent **C:** Sample WP **D:** Sample PE **E:** Sample Trichloromethane **F:** Image taken by an optical microscope with 400x zoom.

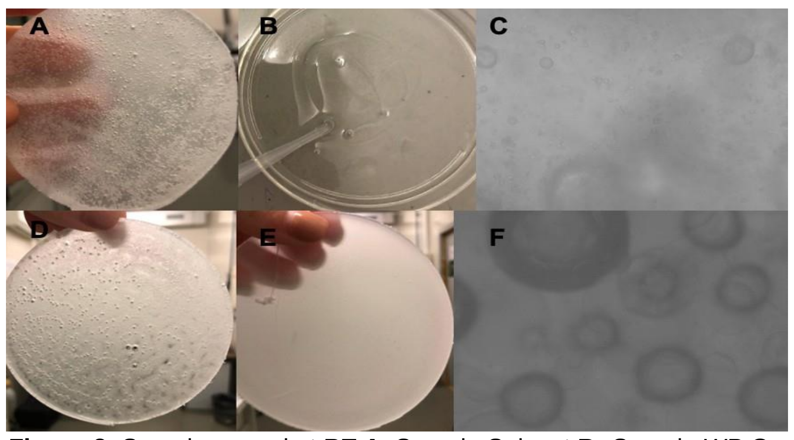

Figure 3. Samples cured at RT **A**: Sample Solvent **B:** Sample WP **C:** Image of PE sample observed at optical microscope with a 400x.**D:**Sample PE **E:** Sample Trichloromethane **F:** Image of trichloromethane sample observed at optical microscope with a 400x

Figure 4. Samples with sugar and PDMS

As observed in Figure 2, when curing is carried out at 120 ºC, it is difficult to remove the sample from Petri dish. The strategy used to avoid this was to place a slide in the petri dish, in the area where the slide was located it, which aid the sample peeling. For the remaining samples, the best results were obtained when left at RT.

By comparing all methods (cf. Figure 2,3 and 4), it is possible to observe that the sample with the smallest pores is the solvent sample, while the PE sample has some pores and the trichloromethane sample has no pores or it is not visible with this device.

In method 2 (Figure 4), instead of using a soluble porogen, this experiment was performed using sugar, which is consider a solid porogen. Figure 4 show the sample obtained after curing and sugar remove.

In order to try to improve the previous results, another procedures with SDS was tested. Once DI water is considering a porogen, a solution with 1% of SDS in DI water was prepared and added to PDMS with a mass percentage of 1,5,8 and 10%. Sample were analyzed by optical microscope. Figure 5 shows the results obtained with the increasing amount of SDS in DI water solution.

As it possible to observe, by increasing the amount of SDS in DI water solution it increase the porosity but decrease the transparency of the sample. Also, although the porosity was increased, there is no connection between the pores, which could affect the permeability.

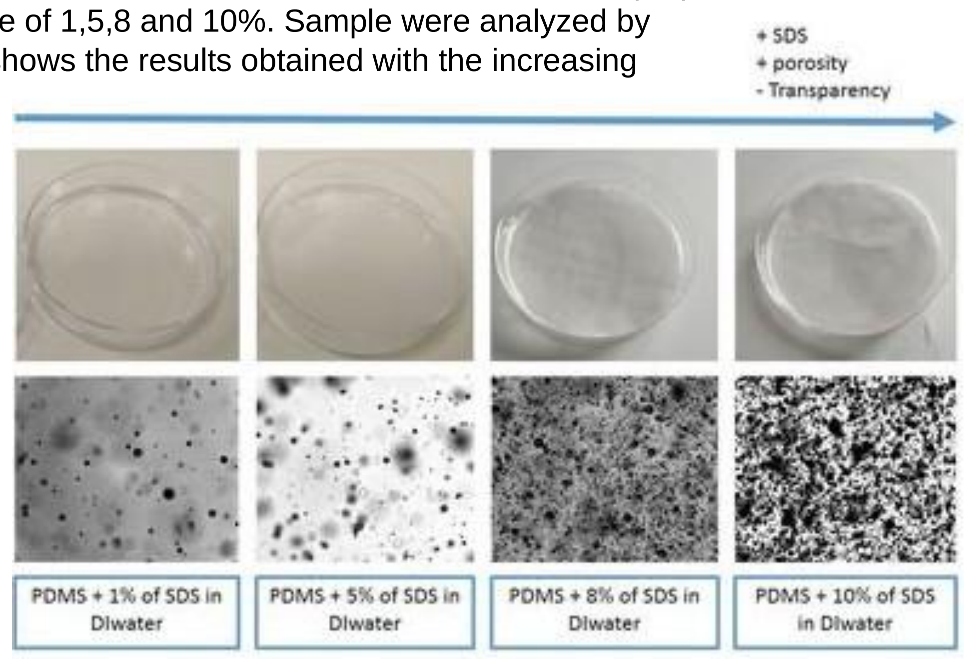

Figure 5: Samples with and increase amount of SDS in Diwater solution

PDMS PERMEABILITY TEST

Air permeability tests (R) were performed and the results obtained are described in Table 2. Although there is an increase in porosity with the increase in the percentage of SDS, the pores are not interconnected and, as such, the air permeability of these samples proved to be null. The minimum air flow for samples to be considered breathable is 69 m^2/s. Although the permeability of sugar stood out compared to the other samples, no sample proved to be suitable for use in masks as they are not breathable.

As future work, we suggest to study the combination of sugar or other solid porogens with Petroleum ether. Since the percentage of porous decrease transparency, the porous should be located at the nose area.

Table 2: Permeability to air

Sample	R (m^2/s)
Petroleum ether RT	8.69
Trichloromethane RT	0
Solvent RT	0
5% of SDS in DIwater	0
8% of SDS in DIwater	0
10% of SDS in DIwater	0
Sugar 6:1	23.2

References

[1] Howard J, Huang A, Li Z, Tufekci Z, Ždímal V, Westhuizen H-M, et al. Face Masks Against COVID-19: An Evidence Review2020.
[2] Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. Journal of Autoimmunity.
[3] Javid B, Weekes MP, Matheson NJ. Covid-19: should the public wear face masks? 2020;369:m1442.
[4] Chodosh J, Weinstein BE, Blustein J. Face masks can be devastating for people with hearing loss.

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