

Impact of Sintering Temperature on Silica Water Filter Fabricated via Cold Isostatic Pressing

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Abstract

This study investigates the effect of sintering temperature on the properties and performance of silica water filters fabricated using the Cold Isostatic Pressing (CIP) method. Silica samples were compacted using CIP and sintered at three temperatures: 1000°C, 1100°C, and 1200°C. Scanning Electron Microscopy (SEM) was used to observe the microstructure and grain bonding. Physical properties such as porosity, density, shrinkage, and water absorption were evaluated to understand the influence of sintering conditions. Filtration performance tests were conducted to assess the efficiency of each sample. The findings aim to identify the optimal sintering temperature for producing high-performance silica water filters with improved structural integrity and filtration efficiency.

1. Introduction

The demand for clean water has escalated globally, and as a consequence, the development of reliable water filtration systems has become a significant area of research. In many parts of the world, access to potable water remains limited, which has led to the exploration of new materials and techniques to produce cost-effective filtration systems. Agricultural waste materials, particularly rice husk (RH), have gained attention for their potential in generating silica-based materials suitable for filtration applications. Rice husk is rich in silica, accounting for approximately 20% of its composition. Through controlled combustion, the organic content of RH is removed, yielding rice husk ash (RHA) that contains amorphous silica. This silica can then be processed into ceramic materials that possess the appropriate physical and chemical characteristics for water purification [1].

Cold Isostatic Pressing (CIP) is a promising fabrication technique for producing high-density, uniform ceramic filters. By applying isostatic pressure through a fluid medium, powders are compacted uniformly in all directions, eliminating internal voids and enhancing structural integrity. Following the CIP process, sintering is employed to induce particle bonding and densification at elevated temperatures. The sintering temperature plays a pivotal role in determining the final microstructure and performance of ceramic materials. It influences grain growth, pore closure, densification rate, and mechanical properties, all of which directly affect filtration performance. Therefore, identifying the optimal sintering temperature is crucial for maximizing filter durability, porosity, and contaminant removal efficiency [2].

This research investigates the impact of different sintering temperatures, specifically 1000°C, 1100°C, and 1200°C, on silica water filters produced from RHA using the CIP method. The study aims to determine how thermal treatment affects microstructural development, mechanical stability, and filtration efficiency. By systematically analyzing these variables, the study seeks to contribute to the optimization of ceramic water

filters fabricated from agricultural waste, ultimately offering a sustainable and effective solution to global water scarcity issues [3].

2. Methodology

2.1 Sample Preparation

Rice husk silica is used as a material to produce a water filter. Rice husk is burned at 500°C for 2 hours. Before mixing the rice husk ash with a binder, the material needs to undergo a sieving process to characterize its particle size distribution. The mixing process involves combining 88%wt rice husk silica with 12%wt binder. Table 1 shows the number of samples that have been used for physical testing and microstructural analysis.

Table 1 Number of samples for testing

Sintering Temperature [2]	Sample	Silica Composition %	SEM	Density & Porosity	Filtration Efficiency
1000	(a)	88		3	
	(b)			3	
	(c)			3	
1100	(a)			3	
	(b)			3	
	(c)			3	
1200	(a)			3	
	(b)			3	
	(c)			3	
TOTAL				27	

2.2 Cold Isostatic Pressing (CIP)

CIP is known as hydrostatic pressing. After mixing, the powder is moistened with a suitable liquid to make it easier to handle. This damp powder is evenly loaded into a flexible mold, which is then sealed tightly to prevent leaks. The mold is placed in a pressure chamber where it is compressed evenly from all directions using liquid pressure. Finally, the mold is opened, and the compacted material is carefully removed. Fig. 2 shows the schematic diagram of the CIP processes. This compaction process ensures that the silica and binder particles are closely packed to create a strong and durable structure [4]. Fig. 3 displays the compacted green body of the filter.

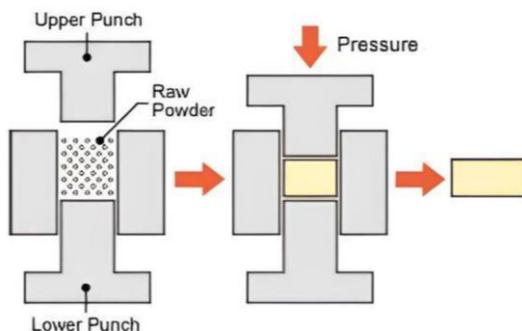


Fig. 2 Cold Isostatic Pressing process

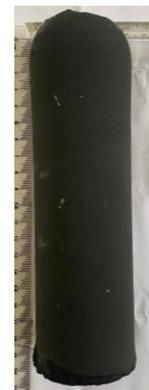


Fig. 3 Compacted green body

2.3 Sintering Process

The green bodies were subjected to a sintering process in a programmable furnace. Sintering was conducted at three different target temperatures: 1000°C, 1100°C, and 1200°C. The sintering profile is shown in Fig. 4. The sintering process aimed to induce particle bonding, reduce porosity, and enhance the overall mechanical stability of the filters [5].

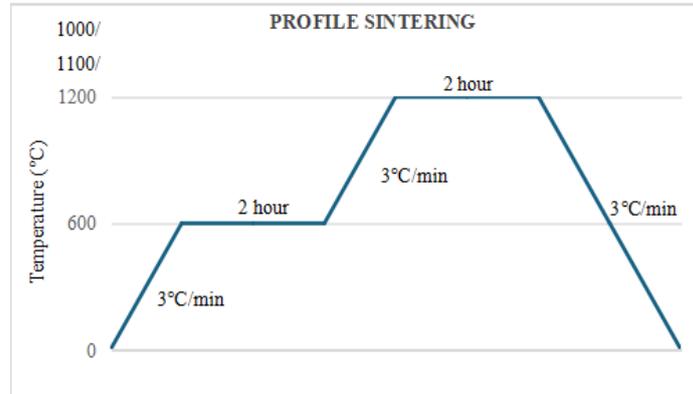


Fig.4 Sintering profile

2.4 Physical Testing

There were several tests done on the sample silica water filter to observe and analyze the performance and characteristics. The shrinkage test, porosity and density test, and water absorption test. Density and porosity properties of the samples were determined using the Archimedes' method. This test is performed to determine the density and porosity value of the sample after the sintering process.

To calculate the value of density and porosity, formulas in Equations 1 and 2 are used, where W_w , W_d , and W_s are the weights of the sample at the conditions of wet, dry, and suspended in water, respectively.

$$\text{Apparent Porosity, } \frac{(W_w - W_d)}{(W_w - W_s)} \times 100\% \quad (1)$$

$$\text{Bulk Density } \rho, \quad \frac{W_d}{(W_w - W_s)} \times 100\% \times \rho \quad (2)$$

2.5 Microstructure Analysis

Analysis of the microstructure surface of the sample was done by using the Scanning Electron Microscope (SEM). It is important to observe grain arrangement, pore structure, and surface morphology, which affect the filter's strength and performance.

2.6 Water Filtration Test

The final step in evaluating the silica samples is testing the effectiveness in actual water filtration. After undergoing sintering at different temperatures, the samples were tested to observe the efficiency of filtered water. Fig. 5 shows the water filtration system.

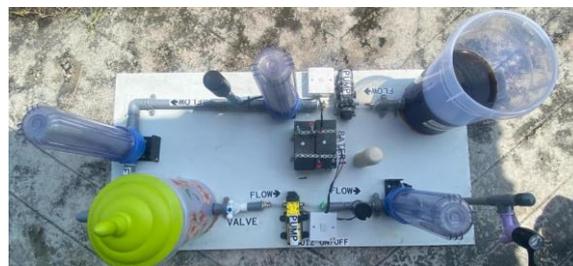


Fig.5 Water filtration system

3. Results and Discussion

3.1 Shrinkage Test

A shrinkage test measures the reduction in size or volume of a material after sintering processes. This helps determine the sample’s potential to shrink under certain conditions. The trend indicates that as the sintering temperature increases, the percentage of shrinkage also rises. At 1000°C, the average shrinkage is the lowest among the three temperatures, with a moderate reduction in sample dimensions which is 2.93% (Fig. 6). This suggests that the initial stages of particle bonding and densification are occurring, but the process remains incomplete at this temperature [6].

The most substantial shrinkage occurs at 1200°C, where the average percentage reaches its highest value. This is an indication of strong sintering activity, with a higher degree of densification occurring due to elevated atomic mobility [7].

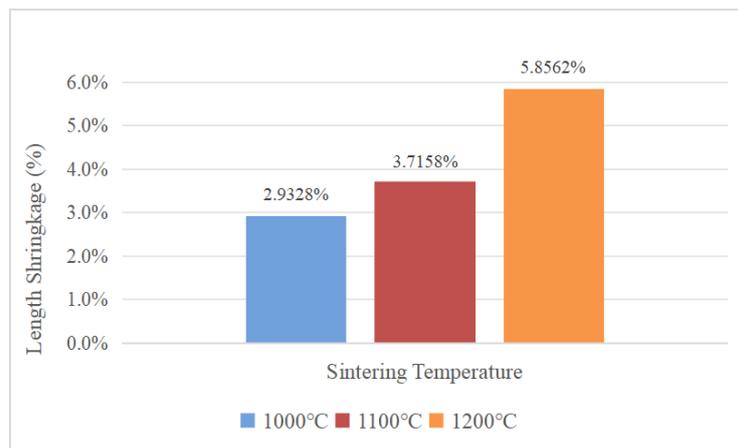


Fig. 6 Linear shrinkage of the filter at different sintering temperatures

3.2 Porosity and Density Test

The percentage calculation of porosity and density tests within the samples was being collected using the formula. Fig. 7 and Fig. 8 show the changes of porosity and density due to different sintering temperatures. The apparent porosity is highest at 1000°C, with a value of 42.57%. Meanwhile, at 1200°C, the porosity drops more significantly to 39.12% which leads to greater particle diffusion and closing off more pore spaces.

The average density at 1100°C is 127.79, which reflects the initial stage of densification. Meanwhile, at 1200°C, the highest density is recorded at 131.88, which indicates that the material has undergone further densification. The structure is more compact, resulting in greater resistance to breakage and higher mechanical stability.

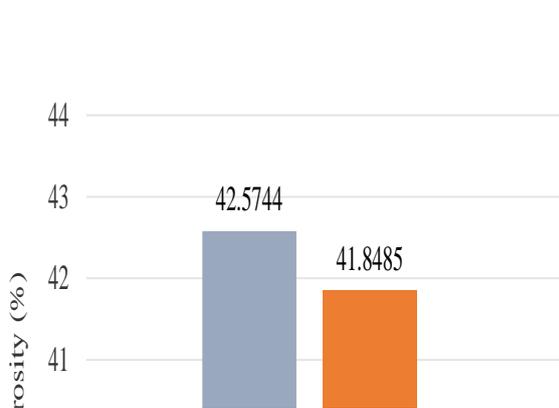


Fig.7 Apparent Porosity at different sintering temperatures

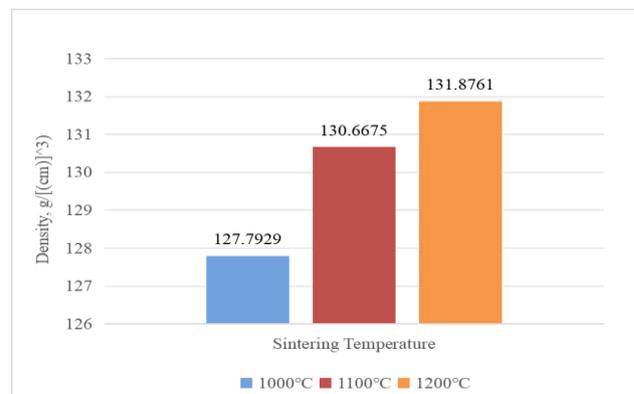


Fig.8 Density at different sintering temperatures

3.3 Water Absorption Test

At 1000°C, the sample has a water absorption rate of 44.98% (Fig. 9), suggesting a relatively high number of open pores that allow water to be absorbed into the material. Meanwhile, at 1200°C, water absorption rises to 46.19%. This could be due to changes in the microstructure, such as the formation of more connected or larger pores during the high-temperature sintering process.

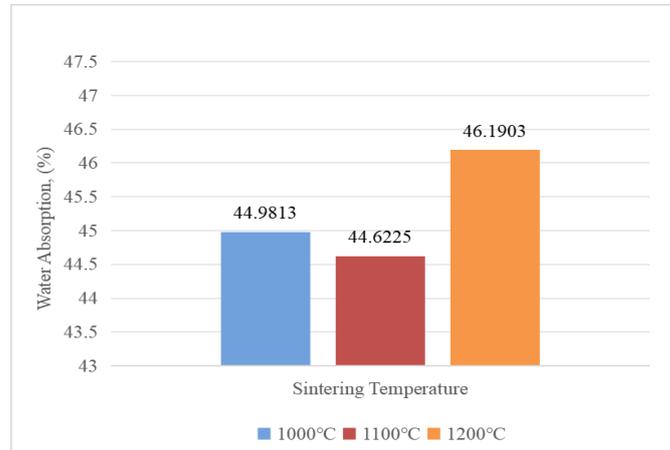
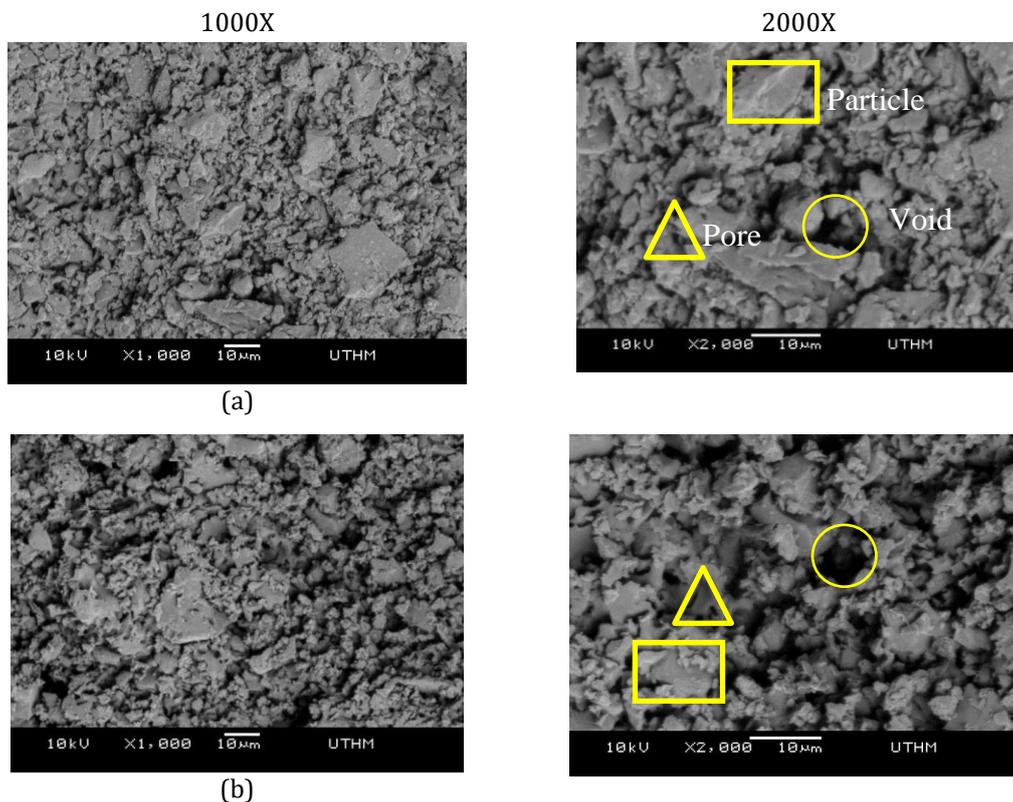


Fig.9 Water absorption of the filter at different sintering temperatures

3.4 Morphology

SEM analysis was used to observe the surface morphology of the samples sintered at 1000°C, 1100°C, and 1200°C at 1000x and 2000x magnification. These images allow visual comparison of grain bonding, pore size, and surface compactness between the three different sintering temperatures. At 1000°C, the microstructure clearly shows many pores throughout the surface (Fig. 10). These pores appear irregular and widely distributed, indicating that the bonding between particles is still weak. The structure is less compact which is the sample is not yet fully dense.



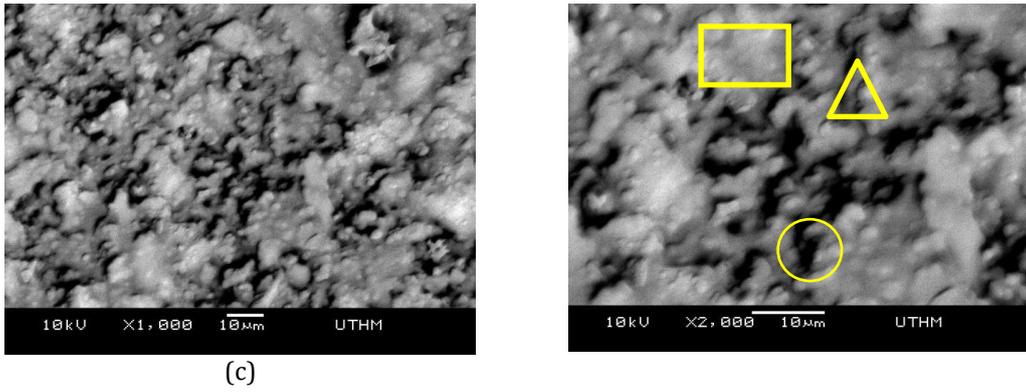


Fig.10 SEM morphologies of the sintered sample at 1000 °C

At 1100°C, the surface appears more compact, and the grain boundaries are more connected (Fig. 11). The particles have started to bond more strongly and resulting in better densification

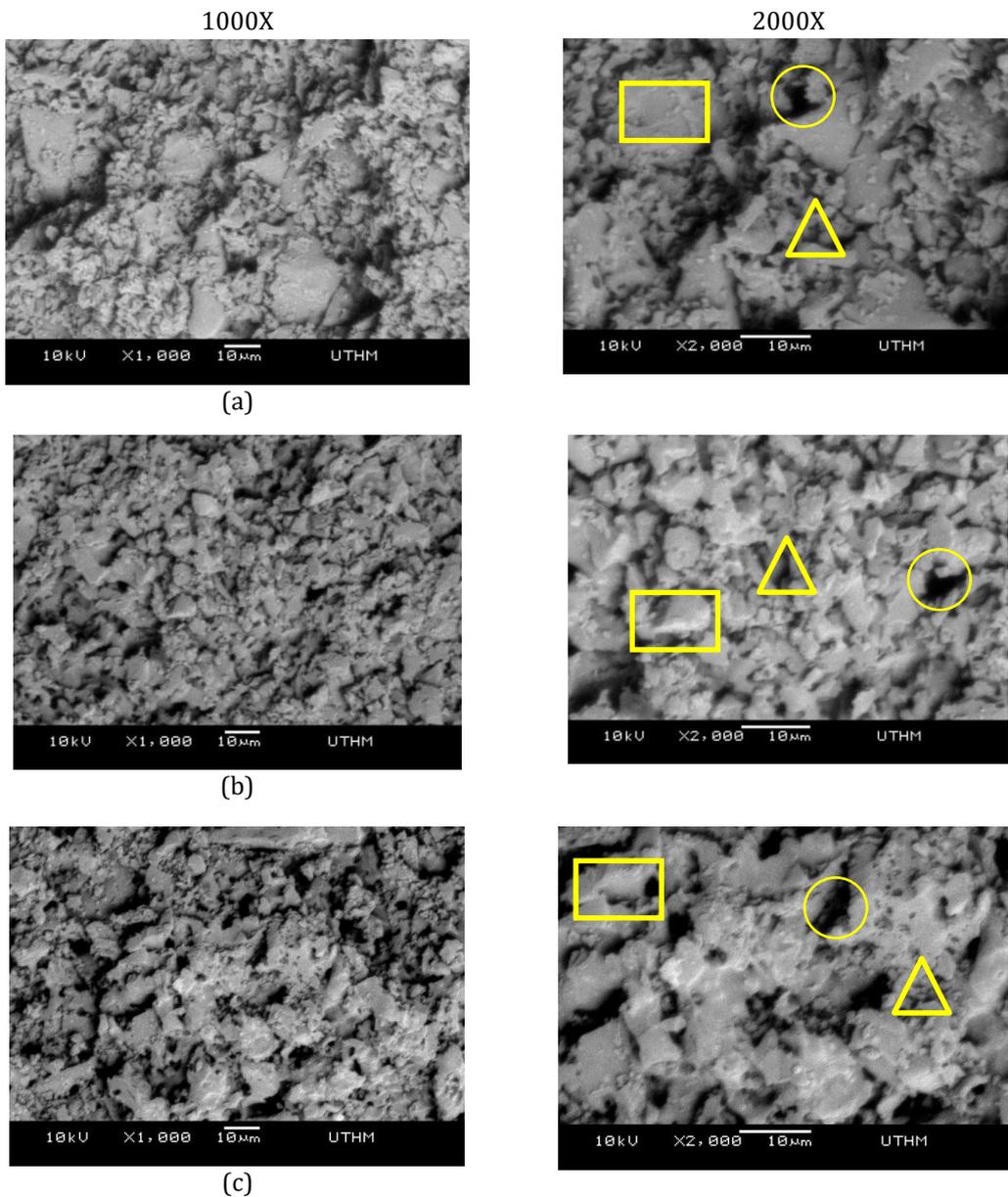


Fig.11 SEM morphologies of the sintered sample at 1100 °C

The structure shows very few visible pores, and the surface is much more compact at 1200°C than the previous two samples (Fig. 12). The grains appear larger and more bonded, which indicates a high level of densification. The sample at this temperature has undergone strong particle fusion, which reduces porosity significantly.

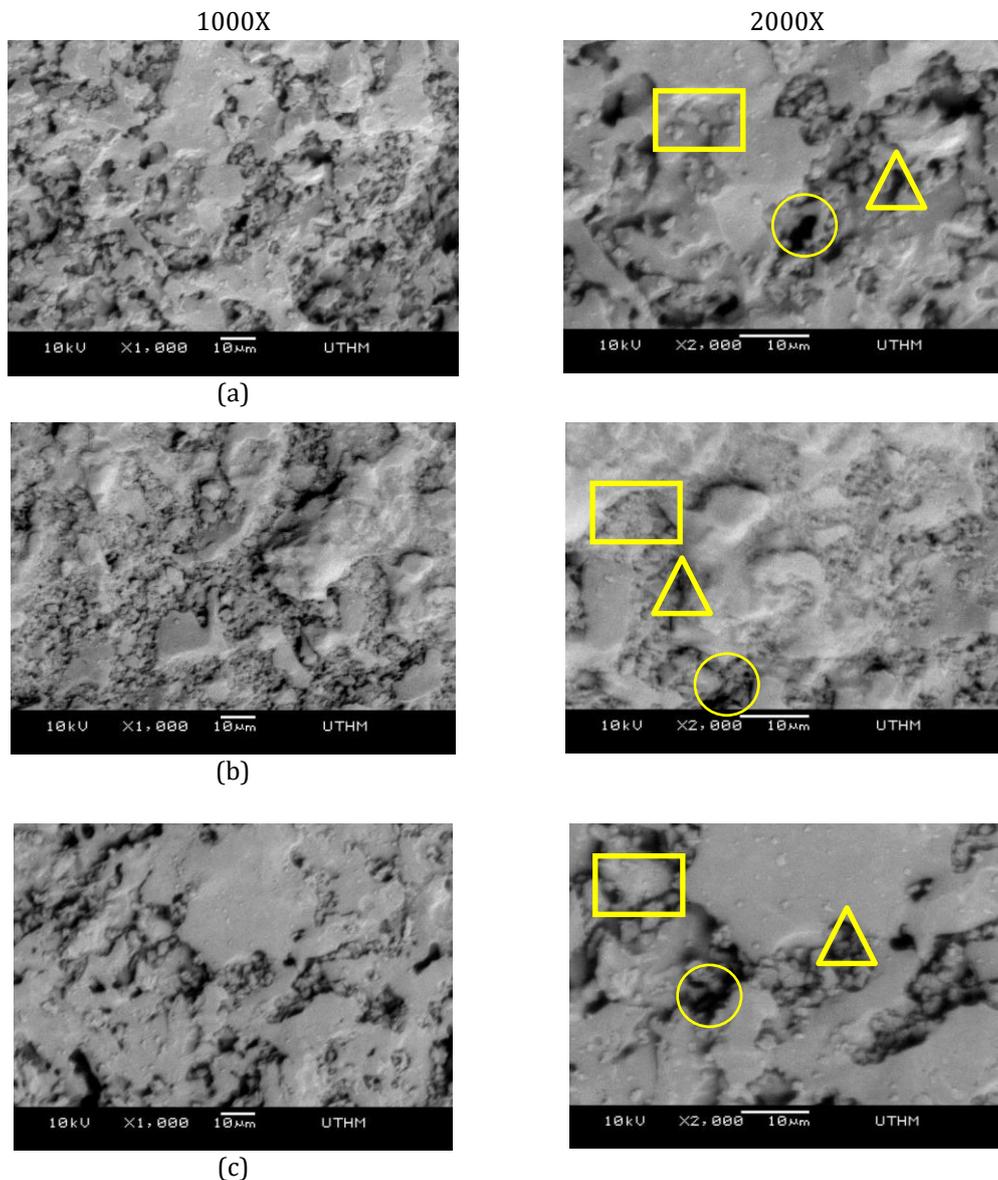


Fig.12 SEM morphologies of the sintered sample at 1200 °C

3.5 Water Filtration Test

The performance was observed by measuring how much water was filtered over time using plastic cups. The test involved collecting water in cups every five minutes and observing the flow rate and clarity. The performance was then compared based on how many cups were filled and how quickly the process was completed.

Fig. 13 shows that at 1000°C, 10 cups were used in total, which took around 45 minutes. This indicates that although the material is porous, it may not filter water very efficiently. At 1100°C, the total number of cups used was 9, taking around 40 minutes. This suggests that filtration performance improved slightly, likely due to better structural integrity and a more refined pore structure. The best performance was recorded at 1200°C, where only 7 cups were used over 30 minutes. This means the sample filtered the water more quickly and effectively. The higher densification at this temperature produced a more stable filter with smaller but well-distributed pores.



Fig.13 Comparison of the performance between different temperatures

4. Conclusion

This research investigated the effect of sintering temperature on silica water filters produced using the Cold Isostatic Pressing (CIP) method. Filters were successfully fabricated and tested at different temperatures, with evaluations including shrinkage, porosity, density, water absorption, and filtration efficiency. SEM analysis revealed structural changes, particularly in pore distribution and particle bonding, as temperature increased. Results showed that higher sintering temperatures led to improved densification, indicated by greater shrinkage, increased density, and reduced porosity. Filters sintered at 1200°C demonstrated the best overall performance with a compact microstructure and the fastest filtration rate, confirming it as the most effective temperature for achieving both strength and efficiency.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The author solely conducted all aspects of this project, including sample preparation, sintering experiments, data collection, microstructural and filtration analysis, as well as the writing and compilation of this final year project report titled *“Impact of Sintering Temperature on Silica Water Filter Fabricated via Cold Isostatic Pressing.”*

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