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Study of Corrosion behavior of silicon-based ceramics in NaOH and Jarul leaf solution

A.K.M. Parvez Iqbal[1], Nayem Hossain[1,*]

[1] Dept. of Mechanical Engineering, College of Engineering Technology, International University of Business Agriculture and technology - IUBAT

*Corresponding author, E-mail: nayen.hossain@iubat.edu

ABSTRACT: *This paper represents the corrosion behavior of silicon-based ceramics composed of silicon, aluminum, magnesium, and iron in HCl and Jarul leaf juice intending to find a suitable solution that makes minimum corrosion. Four different solutions of HCl of Ph value of 0.86, Jarul leaf juice of Ph value of 4.97, 60% HCl with 40% Jarul leaf juice of Ph value of 1.13, and 40% HCl with 60% Jarul leaf juice of Ph value of 1.31 were prepared. At first, the weights of the four samples of silicon-based ceramics were taken. Then they were kept in four different solutions for 30 days. Again, the weight of each sample was measured and compared with the weight of before 30 days, the weight difference was found. The effect of corrosion on the surface of each material was studied. Finally, morphological analyses of samples are performed by scanning electron microscopy.*

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KEYWORDS: Corrosion, HCl, Jarul Leaf, Ceramics, SEM

1. Introduction

The corrosion behavior of silicon nitride (Si_3N_4) ceramics with a porosity of 46% at 1473–1773 K under different conditions including dry O_2, O_2 containing 20 vol% H_2O, and Ar containing 20 vol% H_2O was investigated and compared. The results showed that the porous Si_3N_4 ceramics has a good oxidation resistance up to 1473 K. Their corrosion behavior depends on the temperature and atmosphere. The morphology of the reaction product is highly affected by water vapor and thus accelerates the corrosion rate due to its specific inward diffusion mechanism and devitrified effect at high temperature (Hou et al., 2016).

Diluted aqueous HCl, H2SO4 or H3PO4 solutions at a temperature of 390° C and a pressure of 27 MPa were utilized to investigate the changes in microstructure and phase composition of ceria stabilized tetragonal zirconia polycrystals (Ce-TZP), magnesia and yttria partially stabilized zirconia [(Mg,Y)-PSZ] and magnesia partially stabilized zirconia (Mg-PSZ).In that study, it was observed that Ce-TZP is resistant against the corrosion under these conditions in HCl, while Mg-PSZ is severely corroded and (Mg,Y)-PSZ undergoes a surface tetragonal to monoclinic phase transformation. Severe weight losses and transformation to the monoclinic phase on the surface were observed for all investigated zirconia ceramics in H_2SO_4. Only a small weight gain and a slight increase of m-phase on the surface of the ceramics were found in H_3PO_4 (Michael et al., 1998). Meanwhile, the same materials have been utilized to investigate the electrochemical corrosion behavior using H_2SO_4 at the same conditions as mentioned earlier. A systematic local measurement of the thickness of the oxide layers was carried out. The measurements showed the formation of SiO_2 surface layers with thickness up to 125 µm. The measured values also showed a strong deviation from grain to grain. The thickness of the layers does not correlate with the crystallographic orientation of the grains or the SiC-poly types. The data indicate that the behavior is caused by the variation of the resistivity of the grain boundaries. The measured thicknesses as a function of the electrical charge transferred indicate that the electrochemical oxidation results in the SiO_2 and carbon dioxide (Herrmann, Sempf, Kremmer, Schneider & Michaelis, 2014).

Jarul leaf is used for the treatment of diabetic [Harde Pinal A. and Shah Mamta B, 2011]. It is also used as purgative, deobstruent, and diuretic [1959]. Phytochemical studies showed the presence of triterpene acids like corosolic acid, ursolic acid, oleanolic acid, maslinic acid, asiatic acid, and arjunolic acid [Wenli H et al., 2019, Okada Y et al., 2003]. Ceramic containers are normally used to carry various types of medicines. That is why to conduct research on corrosion with jarul leaf and ceramic is necessary.

This article focuses on investigating the corrosion behavior of a novel composition of silicon-based ceramics in various liquid mediums such as HCl and Jarul leaf juice as the applications of ceramics materials are increasing day by day

Table 1: Chemical composition of disc (wt%).

Mg	Al	Si	Fe
2.56±1.00	31.05±0.56	64.12±0.80	2.26±0.20

2. Methodology

The samples for the experiment were prepared by the combination of Magnesium, Aluminium, Silicon, and Iron. The chemical compositions for the samples are illustrated in table 1.

The samples were prepared through several processes. Powders of above mentioned

composition were mixed followed by liquefying them. This liquid composition was passed the rolling process to obtain the uniformity of the composition. The rolling process has been carried out about 30 minutes. Then the casting process has been completed by pouring the liquid composition into the mold cavity and leaves it for 4 hours to become solid. Finally, hardening process has been carried out at 1573 K for 6.5 hrs. The samples were prepared by FARR CERAMICS Ltd

Four different solutions have been used for this research. HCl solution has been collected from laboratory and its Ph value has been measured. The measured Ph value was about 0.86 that indicate strong acidic characteristics of HCl solution. Locally collected Jarul leaves have been washed and dried up followed by blending to obtain the juice. Water has been used as a solvent to prepare the solution. The measured Ph value of the prepared Jarul juice was about 4.97 that indicates lean acidic characteristics of the juice. Other two solution of this research were 60 wt% HCl, 40 wt% Jarul juice with ph value 1.13 and 40 wt% HCl, 60 wt% Jarul juice with ph valued 1.31. Four samples have been immerged into the four different solutions. Table 2 illustrates the samples and their corresponding solutions.

For a uniform corrosion impact for 30 days or similar is important because the increasing of the impact is time depended. On the other hand, in fewer days it becomes difficult to get corrosion impact on the ceramic. The effect of different solutions on the surface of the samples has been found in this study.

When the ceramic sample is kept in the HCl solution, hydrochloric acid reacts with the components of ceramic and produces proton in the solution. Some other compounds are formed with the ion such as magnesium cloride, aluminum cloride, silicon cloride, iron cloride. In each chemical reaction electron is produced which indicates the electrochemical corrosion in the alkaline solution (Dennis W. Readey, 1998). The following mechanism may happen during the time of corrosion

$HCl + Mg = MgCl_2 + H^+ + e^-$
$HCl + Al = Al_2Cl_3 + H^+ + e^-$
$HCl + Si = Si_2Cl_3 + H^+ + e^-$
$HCl + Fe = Fe_2Cl_3 + H^+ + e^-$

After the completion of the experiment the samples were removed from the solution and then the samples were dried and then the samples were taken for SEM test.

3. Result and Discussion

Fig.1(a) indicates a slight increment of weight after the experiment. Before the experiment the weight of the sample 1 was 3.07 gm, while after the experiment it becomes 3.08 gm by increasing 0.01 gm. Fig. 1(a) in which the weight of the sample 1 increased slightly after one month, in Fig. 1(b) the weight of the sample 2 increased a bit reaching 2.57 gm from 2.56. Here, the weight of the sample 2 increased by 0.01 gm. On the other hand, the weight of the sample 3, in Fig.1(c), is decreased. The initial weight of the sample 3 was 3.71 gmand it is decreased by 0.01 gm and reached at 3.70 gm. The weight loss may occur because of the chemical reaction of HCl acid and Jarul leaf with the ceramic sample and the

Table 2: Samples with Ph value

Samples	Solution	Ph value
Sample - 1	HCl (100%)	0.86
Sample - 2	HCl (60%) + Jarul leaf juice (40%)	1.13
Sample - 3	HCl (40%) + Jarul leaf juice (60%)	1.31
Sample - 4	Jarul leaf juice (40%)	4.97

formation of proton and other compounds (Han et al., 2018, Jothiet al.,2014). Fig. 1(d)

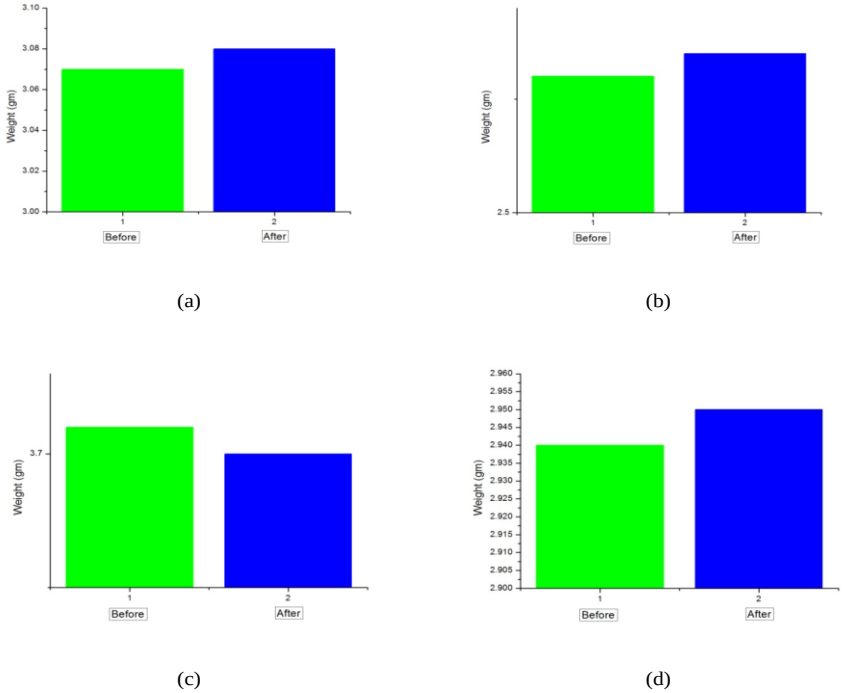

Figure-1: Comparison of weight of the samples before and after the experiment (a) HCl, (b) 60% HCl and 40% Jarul leaf, (c) 40% HCl and 60% Jarul leaf and (d) Jarul leaf

shows the similar characteristic of Fig. 1(a) and 1(b). The weight of the sample 4 increased by 0.01 gm after the experiment. Initially the weight was 2.94 gm and the final weight reached at 2.95 gm. The reason for the increment of the weight of the samples may occur because of the formation of various compounds and Jarul on the surface of the ceramic. In some samples of ceramics, the weight increased because of the infiltration due to capillary action [Sanchita Baitalik, Nijhuma Kayal, article in press, S. Whitaker 1986].

The SEM images of the corroded surface show the surface morphology at 50 µm magnification. Fig. 2 shows the surface SEM micrographs of the corrosion layer produced by the solutions in one month of the corroded ceramics. A thin and homogeneous layer was produced on the ceramic surface. The surface was partially covered by oxide layer (Kondo et al., 2010; Nishimura et al., 2000). Because of being remained under liquid solution for long time few cracks were

formed (She, Ohji, 2002). Surface corroded by the acid is seen in Fig. 2(a). Some cavities are formed in Fig. 2(b) (Wang et al.,2015). Layer of acid and Jarul leaf is seen in Fig. 2(c).

4. Conclusion

The purpose of the corrosion test of silicon-based ceramic in the solution of hydrochloric acid, Jarul leaf and their mixture was to find the suitable solution that makes less corrosion on ceramic. After the experiment it was found that the Jarul leaf juice produces less corrosion on ceramic compared to HCl solution. The weight of all the samples increases except the sample 3. To obtain more suitable solution, more green solution can be used for the future experiment

(a) (b) (c)

Figure-2: Surface morphology of different samples after corrosion testing in the solution of (a) HCl, (b) 60% HCl and 40% Jarul leaf and (c) 40% HCl and 60% Jarul leaf.

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