

Development of Bipolar Plates Using Expanded Graphite as a Raw Material

Supriya Jadhav¹, Sneha Dhole², Sheetal Suryavanshi³, Kavita S. Suranje⁴, V S Galphade⁵

U G Student, Department of Metallurgy and Material Science, College of Engineering, Pune, India¹

U G Student, Department of Metallurgy and Material Science, College of Engineering, Pune, India²

U G Student, Department of Metallurgy and Material Science, College of Engineering, Pune, India³

Assistant Professor, Department of Applied Science, College of Engineering Pune, India⁴

Assistant Professor, Department of Metallurgy and Material Science, College of Engineering, Pune, India⁵

ABSTRACT: The bipolar plate is a major component of the proton exchange membrane fuel cell (PEMFC). It is the costlier component of PEMFC stack. Expanded graphite-polymer composites were fabricated by compression moulding. Expanded graphite (EG), which is synthesized by heating of natural graphite at 750°C. The expanded graphite synthesized in this study has 20% of volume expansion. Expanded Graphite mixed manually with Resole Phenolic resin. Expanded graphite provides electrical conductivity and phenolic resin provides mechanical strength to the bipolar plate. Expanded-polymer composite has shown maximum electrical conductivity. On deviation from metallic materials expanded Graphite-Polymer composite bipolar plate are found promising for PEMFC providing the values targeted toward US-DOE.

KEYWORDS: Natural Graphite, EG, Resole resin, PEM

I. INTRODUCTION

Proton exchange membrane (PEM) fuel cells are considered a promising candidate for zero emission power source required for environmentally friendly transportation and stationary applications. It gives high current density and employs low operating temperature and pressure. However, practically, the connection of single fuel cell in series, called fuel cell stack, is usually done in order to increase the cell potential. Hence, bipolar plate is used to separate the adjacent cell in the stack and conduct the electrons. In addition, bipolar plate also provides the fuel gas and the oxidizing gas, water and heat management within the cell. As a consequent, materials used in the fabrication of bipolar plate have to resist the fuel cell operating environment and the fabrication process should not be complicated [1]. Eighty percent of the fuel cell stack's weight is the bipolar plate weight [2]. Thus, the development of bipolar plate for stack cell focuses on its properties, cost and weight of the entire fuel cell.

The conventional materials for producing bipolar plates are graphite (or graphite-polymer composites) or metal. Graphite plates were preferred over the metallic plates because of their high corrosion resistance and low density. On the other hand, the disadvantages of graphite are difficulties in machining (or in case of graphite-polymer mixtures in moulding) and its brittleness. Graphite-based polymer composite bipolar plates have potential to replace graphite plates, because they offer the advantage of greater ease of manufacturing than graphite plates.

Natural graphite show layered structure with a c-axis lattice of 0.66 nm. Moreover, there are no reactive ion groups on the graphite layers. It is rather difficult to intercalate organic molecules or polymers directly into the interlayer of graphite. The expanded graphite, a kind of modified graphite, contains multi-pores ranging from 2 to 10 nm. The expanded graphite keeps a layered structure similar to natural flake graphite but with large interlayer spacing. The properties of the multi-pores, functional acids and OH groups make expanded graphite have good affinity to both

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organic compounds and polymers, therefore, some monomers, initiators and polymers are to be absorbed into the pores and galleries of expanded graphite by proper method to produce conductive composite.

Therefore, worldwide efforts are going on to develop lightweight and ductile bipolar plate from alternate materials that should satisfy the required series of properties of bipolar plate as per U.S. DOE technical targets [19]. EG is a kind of modified natural graphite possessing high electrical conductivity and lower density ($0.01\text{--}0.015\text{ g/cm}^3$) than that of natural graphite (2.2 g/cm^3). Thus it can be one of the alternate materials for the development of composite bipolar plates.

II. EXPERIMENTAL

A. Materials:

Filler material: Expanded Graphite
Binder: Phenolic Resin (resole type)

B. Preparation of Expanded Graphite:

About 25gm of natural graphite kept in crucible and heated to temperature of 750°C and kept at this temperature for 5 minutes. Then, slowly cooled in furnace. This results in formation of expanded graphite. Volume expansion is about 20 times original volume.

C. Preparation of composite:

Hot compression molding process is used for making composite of expanded graphite and phenolic resin. Where, expanded graphite gives good electrical conductivity and good surface finish. Also, phenolic resin gives high mechanical strength to the bipolar plate. It is thermosetting type of polymer. Expanded graphite is mixed manually with phenolic resin in composition 70% of EG and 30% of resole resin. Then mixture is fed to preheated mold. The heating temperature is 150°C and curing times is 15 minutes. The molding pressure is about 100 kg/cm^2 . It selected by referring to literature review. The compression is done using Universal Testing Machine. Mold cavity diameter is 30mm. In first case we vary load and keep curing time constant (i.e. 15 min). Also, in second case vary curing time and keep load constant (i.e. 5kN). Because, above this load crack will occur in the compressed pellet. By taking care of this, composite plate i.e. bipolar plate is developed.

III. CHARACTERIZATION

A. Theoretical Density Measurement:

Theoretical densities of all composite sample were calculated by following formula.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Mass is measured by taking weight of the sample and volume is measured by multiplying cross sectional area to thickness of the sample. The diameter of sample is 30 mm.

B. Shore Hardness:

Shore hardness of composite is measured by D type durometer (i.e. ASTM D2240-04). D scale at our dept. Coep Pune. Hardness value mentioned in DOE target were by shore D-scale is 50.

International Journal of Innovative Research in Science, Engineering and Technology

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C. Electrical Conductivity:

Electrical conductivity is characterized by both the methods of in-plane and through-plane methods. The in-plane conductivity was measured using four-probe instrument (Coep, Pune). Through-plane conductivity was measured using KEITHLEY instrument (National Chemical Laboratory Pune). Actual resistance=Observed resistance-Contact resistance (Contact resistance=2.05Ω) Conductivity=1/resistivity(R)

IV. RESULTS AND DISCUSSION

1. Experimental Results:

TABLE 1.COMPOSITION:

Expanded Graphite	Phenolic Resin (Resole)
70	30

TABLE 2. EXPERIMENTAL DETAILS:

Sr No	Force (kN)	Pressure(MPa)	Temperature (°C)	Curing time(min)	Remarks
1	7	10	150	15	Some cracks on surface
2	5	7	150	15	Proper sample with good surface finish

TABLE 3. RESULTS:

Sr No	Pressure (MPa)	Curing time (min)	Hardness shores-d	In-plane Conductivity	Through-plane Conductivity	Density(g/cc)
1	10	15	49	150.2	6.2768	1.44
2	7	15	51	154.9	25.1624	1.88

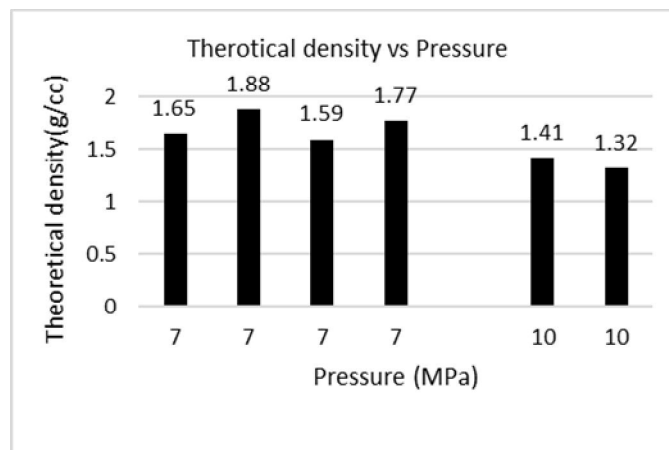


Fig1. Theoretical density Vs. Hot compaction Pressure

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Fig 1. Sample with 7 MPa pressure and 15 min of curing time has highest density i.e. 1.88g/cc. Because, sample with these parameters has good surface finish and less porosity.

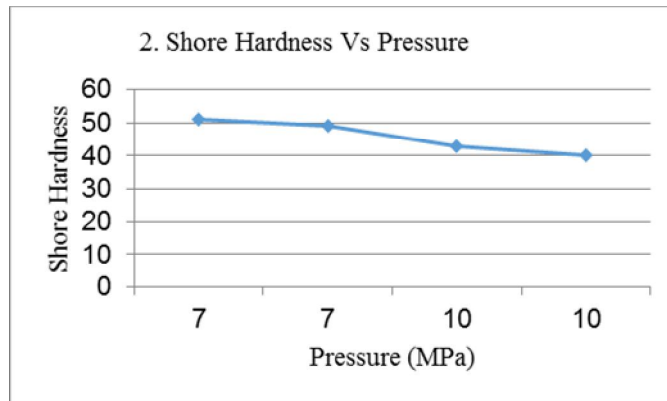


Fig 2. Shore hardness Vs Hot compaction pressure

Fig 2. Sample with 7 MPa pressure and 15 min of curing time has highest shore hardness (i.e. 51). As pressure increases shore hardness decreases.

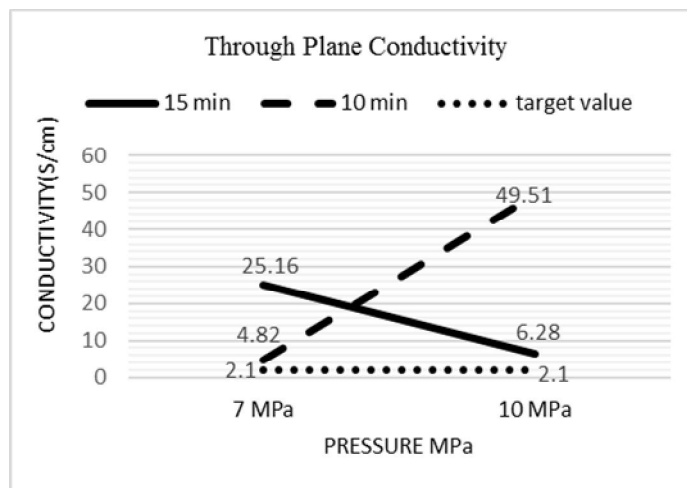


Fig 3. Variation of Through Plane Conductivity with change in compaction pressure and curing time.

Fig 3. Sample with 7 MPa pressure and 15 min of curing time has better through plane conductivity than with 10 min of curing time. As curing time decreases conductivity decreases, because resole resin get less time for curing (i.e. wettability decreases). A sample with 10 MPa pressure has better conductivity than sample with 7MPa pressure. Because, as pressure increases contact point and contact area increases so that conductivity increases.

V. CONCLUSION

- 1) Literature survey have shown that expanded graphite/resin composite is a good material for use in forming fuel cell components due to its maximum conductivity, better corrosion resistance, low cost and ease of processing.
- 2) Use of a binder such as phenolic resin (resole) helps to hold the material together and improve its strength.

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- 3) We found good results with composite of 70:30 expanded graphite and phenolic resin (resole) at 5 kN (i.e. 7 MPa pressure) & 150°C temperature for 15 minutes curing time.

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