White Paper

Surface Roughness of Moulded Graphite Composite Bipolar Plates

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Critical Factors to Achieving an Optimised System - Contact Resistance and Surface Roughness

Whilst remaining chemically "passive", bipolar plates must provide a low resistance path for electron migration within the fuel cell stack. In order to exploit the true potential of the fuel cell stack, the surface science of bipolar plates requires great consideration. This includes an understanding of the homogeneity in surface material, in-plane conductivity, plate porosity, degree of planarity and surface roughness. Of the many vital surface properties, roughness has a major impact on overall stack power efficiency. An extremely rough surface can limit the interfacial interaction with the Membrane Electrode Assembly (MEA). Put simply, by minimising the bipolar plate surface roughness, you reduce the interfacial resistance (for a given stack compression).

By relying on an insulating polymer matrix, most composite bipolar plate manufacturers require secondary surface operations to remove a non-conducting surface coating. General surface treatments will only increase the surface roughness when compared to the high quality, moulded surface finish. However the high post-moulding resistive layer has a negative impact on the output performance of a fuel cell stack, where the degree of surface resistance is directly proportional to the interfacial efficiency of current transfer in a fuel cell stack. These manufacturers must remove the detrimental, electrically insulating coating and accept that the plate's interfacial contact area will always be limited by the additional surface processes. These operations include surface machining, chemical etching and pressurised water ablation, which all adding significant cost to the final product.

To highlight the effects of machining on the plate roughness, figures **1.1** and **1.2** present examples of both moulded and machined flow-field patterned bipolar plates. However smooth both surfaces appear to the naked eye, light scattering measurements show average roughness values of ~660nm for the moulded (Figure **1.1**) and ~2500nm for the machined surface (Figure **1.2**), with the data also presented in Table **1** (Poco graphite plate as reference).

Figure 1.1 & 1.2 Examples of moulded and machined *ElectroPhen*®EP1109 bipolar plate, respectively.

A critical question is then posed - is it possible to overcome this problem, especially when considering larger volume scale-up and mass production? Fortunately the answer is yes - **Bac2 Ltd has solved this issue without the need for surface modification**. Bac2 Ltd utilise the patented conductive polymer, *ElectroPhen®,* as a host binder. The intrinsic conductivity in this host polymer matrix removes any necessity for additional surface treatment or secondary processing.

The route to optimising the moulded plate surface begins at the materials formulation stage. Possessing control over all initial constituents of the final plate composition, Bac2 Ltd has the freedom to tailor each element (host polymer, graphite, catalyst etc), allowing for maximum exploitation of the plate performance. With such a wide range of carbon forms available as conductive filler (natural and synthetic, spherical, flake etc), choosing suitable graphite particle form and size will have a huge effect on the plate properties. For example, in general when considering flake graphite, larger flakes aid the *wettability* of the pre-moulding mix, increase material flow during moulding and enhance surface (in-plane) electrical conductivity of the final plate (although possibly to the detriment of the through-plane conductivity). The choice of graphite will impact greatly on the moulded and machined finish, even when considering more expensive machining technology.

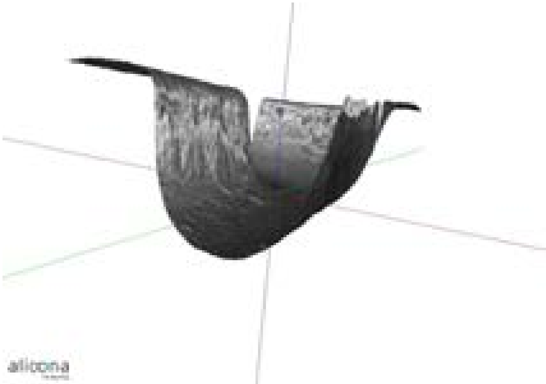
Table 1.1 Average surface roughness for a series of fuel cell bipolar plates (*Courtesy of University of Birmingham, [¥] Bac2 Ltd optical scattering data)

Sample	Average Surface Roughness , R_a (nm)
Moulded *ElectroPhen*® Composite Surface	660*
Machined *ElectroPhen*® Composite Surface	2500¥
Machined Poco Graphite Plate	1060*

Complementing an optimised plate formulation, a true understanding of compression moulding is vital in order to realise the high performance from the final piece part. By matching the appropriate mould settings to the specific plate composition you can optimise the plate performance in the assembled fuel cell stack. Numerous mould tool adjustments and settings can be implemented to reduce the surface roughness of the final moulded product,

- Specific mould tool temperature and pressure settings will assist in minimising roughness and maximise reproducibility of moulded surface finish.
- Chroming the tool face can decrease the degree of surface roughness imparted onto the plate during the moulding process.
- Ensuring adequate venting during the moulding process will minimise residual trapped volatiles within the plate and avoid such negative effects as *dieseling* – the charring of a plate, often noted around the edges and surface of a plate.

Figure **1.3** presents a 3-D reconstruction of a moulded flow field channel (based on SEM imaging). Figure **1.4** presents the corresponding channel surface using white light optical interferometry, showing a minimised surface roughness of ~ 660nm.



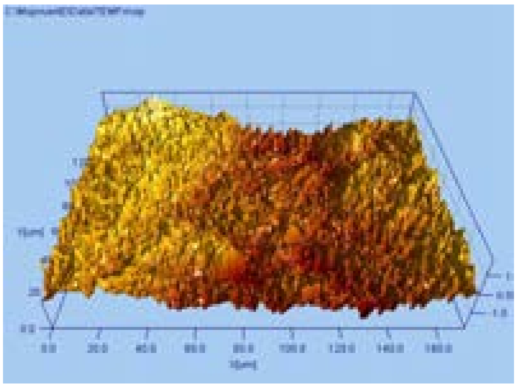


Figure 1.3 & 1.4 Moulded *ElectroPhen*®-based bipolar composite plates, showing 3-D rendered image of the flow-field channel and the associated surface roughness (*Courtesy of University of Oxford*).

The task of reducing interfacial electrical resistance within a fuel cell will not be solved by optimisation of one physical property alone. This necessitates a comprehensive understanding of each individual component within the fuel cell stack and more importantly, how these components interact with their immediate surroundings. In order to meet the expected fuel cell power output demands at a cost effective level, the importance of surface interaction between current collector plate and MEA must not be underestimated.