School of Chemistry

Aims and Objectives: Session 2022-2023

Module CH5716: Processing of Materials

Duration: 20 hours

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(*Module Convenor)

Aims: Advanced functional materials are at the heart of many cutting edge technologies, such as advanced microelectronics or new devices for energy conversion and storage. While the fundamental chemistry and physics of these materials are vital in determining their properties and performance, the final form and microstructure can be equally important in influencing these. This form and microstructure is largely controlled through the processing of the materials and variables such as layer thickness, grain size and porosity can have a profound effect on the final functionality of the material.

The aim of the module is to develop an understanding of various aspects of materials processing and how these influence the final form of the material or device. We will concentrate on ceramics processing for thick and thin film devices with a focus on the former as these are central to many of the devices for the applications outlined above and not as well covered in general texts compared to other forms of materials processing such as those for metals and polymers.

Objectives:

1. Be aware of the various types of thick and thin film processing such as tape casting, screen printing, physical and chemical deposition methods, sol-gel, spray deposition, how these can relate to different device architectures and the importance of process-performance relationships. Discuss the selection of suitable process methods in terms of overall device design, process integration cost and scalability.

2. Review other paste based processes such as calendaring and extrusion which are useful in the production of supports and substrates. Discuss the advantages and disadvantages of these and where they fit into various process scenarios for devices based on advanced functional materials.

3. Understand the mechanism and kinetic limitations of conventional solid-state reactions. Understand the chemistry of sol-gel processing and provide examples of the use of alkoxide and carboxylate precursors to prepare ultrafine oxide powders. Review other solution based methods for fine powder preparation and understand the chemistry of the processes. .

4. Understand the influence of starting powders in slurry and paste based ceramic processing. Discuss how differing powder synthesis routes impact powder properties such as particle size and shape, the impact this can have on pastes and slurry properties and how to modify these by calcination or milling.

5. To be able to discuss the formulation of slurries and pastes for thick film process methods such as screen printing or tape casting. Know the functions of the main constituents in a slurry, preparation methods (such as milling and dispersion), and how to manipulate the formulation and preparation to achieve the desired slurry properties. Compare the advantages and disadvantages of organic versus aqueous based systems.

6. Understand the principles of slurry rheology. Discuss different types of flow exhibited by slurries and what variables can influence this. Understand how to quantify flow in non-Newtonian systems and the importance of measurement technique. Discuss drying of the slurry, the shaping and properties of the green body and how these can influence the final fired ceramic.

7. Understand sintering mechanisms and how raw materials and green body processing influence this. Discuss engineering of microstructures to achieve desired functionality.

8. Understand driving forces for sintering, mass transport mechanisms, and atomic mobility. Solid-state sintering: mass transport mechanisms. Discuss and understand stages of sintering and relation with microstructure development.

9. Understand liquid-phase sintering: thermodynamic and phase equilibria, sintering models, and transient-liquid phase sintering.

10. Reactive sintering processes: reactive sintering, reaction bonding, and reactive hot compaction.

11. Pressure-assisted sintering: effect of pressure in sintering, deformation mechanisms, densification maps, and pressure-assisted sintering processes. Secondary phenomena: phase transformations, Review the effects of constraint on sintering and final microstructure. Application of sintering aids both solid state and liquid phase

12. Control of porosity through slurry formulation, thermal processing and templating. Review graded structures and interfaces, discuss application of composite structures and recent developments in attaining these through infiltration and coating.

13. Case studies of two common thick film processes in more detail, in this case screen printing and tape casting. Review applications of these techniques and understand both the advantages and limitations of each. Be able to discuss the specific slurry characteristics required for each process. Identify some common process issues that may be encountered; be able to suggest possible solutions for these.