Control of Non-Equilibrium and Controllable Interface Approach in Field-Assisted Sintering

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Highlights

- Net shape flash spark plasma sintering is applicable to any material.
- SPS-specific constitutive equation takes into account electric current contribution.
- The concept of controllable interfaces enables SPS scalability.

1. Introduction

High rate field-assisted processing is usually based on various transient thermal and non-thermal phenomena, which, if properly managed, provide unique environment for densification and microstructure retention. Thereby, an efficient field-assisted sintering process utilizes conditions of controlled non-equilibrium [1]. For practical realization of this concept the in-depth analysis of the role of electrical current in mass transport during field-assisted sintering is necessary. This analysis leads to the idea of controllable interfaces.

2. Methods

Ideally, the field-assisted sintering heating pathways should be localized in the areas, where the energy is mostly needed for the efficient deformation and densification. These areas (interfaces) should also have an optimized location and topology to provide the required level of the energy concentration related to the electric current density. If properly designed, these interfaces become controllable in terms of the energy passage [2]. The idea of controllable interfaces facilitates highly efficient energy spending allowing spark plasma sintering (SPS) scalability (*e.g.*, processing of large size components in regular lab-size SPS devices) and net-shaping.

3. Results and discussion

A new constitutive equation of SPS [3], embedded in the finite-element framework, provides a model basis for the controllable interface design. The new controllable interface method represents an efficient way for the mass production of small objects with optimal production time and high material performance. The fabrication of large size objects is possible too but requires a specific design of the electric current path in the Flash SPS tooling to balance the amplified thermal gradients.

4. Conclusions

For the first time, by taking into account the explicit influence of the electric current effect on the SPS densification mechanism, the constitutive equations describing the electric current-assisted hot pressing of conductive powders are developed. The densification mechanism is determined by the inverse regression of the new SPS constitutive equations and by utilizing the experimental results on a conductive powder consolidation with and without the participation of the electric current effect. The developed model provides the theoretical basis of the new method of controllable interfaces which allows: extending flash sintering/SPS to nearly all materials, controlling sample shape, and an energy efficient mass production of small and intermediate size objects.

References

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Keywords
Spark plasma sintering; flash sintering; net-shaping; scalability.