MODELING OF JOULE HEATING IN KNN FLASH SINTERING

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Key Words: FLASH, KNN, TEM, FEM, Joule Heating.

In this work, we propose the use of FLASH sintering as an alternative technique to densify Potassium Sodium Niobate, $K_{0.5}Na_{0.5}NbO_3$, KNN, a piezoceramic with relevant promising applications and a possible viable substitute of lead zirconate titanate based compositions ($Pb_{1-x}Zr_xTiO_3$, PZT). We aim to increase this material performance by densifying KNN ceramics without secondary phase segregation. Furthermore, FLASH will contribute to a more sustainable processing of piezoelectrics as lead-free ceramics at reduced sintering temperature and time.

Our results show that KNN can be FLASH sintered at temperatures as low as 300 ºC, when special sintering atmosphere conditions are considered. Moreover, no secondary phases are segregated, and, highly dense areas can be found. We show that particle amorphization and sliding, as consequence of Joule Heating, are the main mechanisms contributing for KNN FLASH sintering. Transmission Electron Microscopy, TEM, of FLASH sintered KNN ceramics revealed that GBs are amorphous and contain segregated contaminations. It was concluded that Joule heating contributed to reach very high local heating rates up to also high temperatures, causing particle surface melting, amorphization and sliding. In addition, the characteristic cuboid shape of KNN particles allowed to correlate the particle contact geometry with the final microstructure. As shown in fig.1, sharp contacts, as vertex or edges, can even penetrate the faces of the neighbor's cuboid and the amount of produced liquid phase was observed to be dependent on the type of particle contact, decreasing by the following order: vertex-vertex > vertex-face > edge-face > face-face.

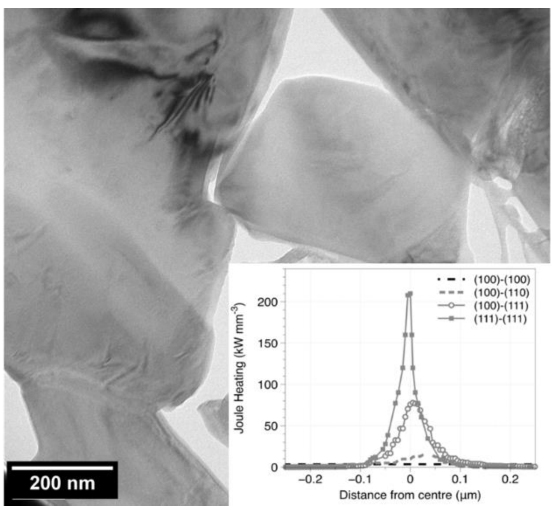

Figure 1 – TEM micrograph of FLASH sintered KNN, with amorphized GBs and penetration of sharp edge trough neighbor face. Overlapped calculated Joule heating for the four considered possible particle contacts.

Finite element modeling, FEM, was used as a tool to model the microstructure of particle contacts and calculate the current density and Joule heating. A coherent relation between the model and TEM experimental observations was found. In the vertex-vertex configuration, an excess of Joule heating that is 250x higher than that in the face-face configuration was found, which can explain the particle penetrations.

Acknowledgments:
This work is financed by Portugal 2020 through European Regional Development Fund (ERDF), in the frame of Operational Competitiveness and Internationalization Programme (POCI), in the scope of the project "FLASH sintering of lead free functional oxides towards sustainable processing of materials for energy and related applications- FLASH", POCI-01-0247-FEDER-029078, and in the scope of the project CICECO- Aveiro Institute of Materials, POCI-01-0145-FEDER-007679 (FCT Ref. UID/CTM/50011/2013), cofinanced by national funds through the FCT/MEC