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Additive Manufacturing – versatile but challenging process

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Additive Manufacturing (AM) is widely known and appreciated due to its flexible and customized manufacturing capabilities. Today, the AM technology has contributed to almost all engineering areas that include mechanical, materials, industrial, aerospace, electrical and most recently biomedical engineering. It is also very useful to manufacture and shaping of structural and functional ceramics. The applicability of AM is shown by appropriate assessment based on the four material systems, namely: (1) AlN -graphene nanocomposite additive manufactured for micro heat exchanger; (3) (2) Inconel 625 – WC composite and (3) KNN (K0,5Na0,5)NbO3 solid solution.

The anisotropic AlN-graphene nanocomposites were shaped by AM technology for micro heat exchanger purposes. The structures, morphologies, and microstructures of those hybrids were examined by X-ray diffraction, SEM and TEM methods. It is showed that additive manufacturing significantly influenced on thermal anisotropy and microstructure appearance. The results were correlated with thermal conductivity of the samples carried out by the laser pulse method - LFA 427 apparatus. The possibility of controlling anisotropy by graphen content and Additive Manufacturing conditions is showed.

Chemically and structurally homogenous Inconel 625 – WC composite coatings were prepared by Additive Manufacturing. Because of chemical composition of Inconel 625 superalloy, secondary carbides of WC, W_2C, NbC, (NbW)C, $W_6C_{2.54}$ and $(W,Cr,Ni)_{23}C_6$ were detected in the intergranular spaces by XRD analysis. They appeared in form of eutectic with typical fishbone-like structure in samples containing increased amount of WC - 30 wt %. High cooling rate during AM was the reason of fine microstructure in produced material. TEM observation showed two types of precipitations: angular carbides and spherical oxides containing increased amount of Cr, Si and Ti.

Among many solid solutions based on potassium niobate, the combination of ferroelectric KNbO3 and anti-ferroelectric NaNbO3 with the (K0,5Na0,5)NbO3 stoichiometry (KNN) is indicated as the most adequate possible replacement for PZT. The solid solutions in this system containing even up to 90% NaNbO3 have a morphotropic boundary. In most cases, the sequence of phase transitions is identical as in pure KNbO3, except for transition from the rhomb to the rhombohedral phase where the phase transition temperature changes a bit depending on chemical composition.

The Additive Manufacturing is very perspective technology for providing wireless power supply to transducers in low-energy measurement, signal or control systems. The KNN piezoelectric generators have a wide application potential in this regard. However it is very difficult to obtain dense sinters from the KNN solid solutions. On one hand, their phase stability is limited to the temperatures (1040°C for potassium niobate and 1140°C for KNN) which significantly limit the sintering process. In addition, small changes in stoichiometry, both towards the potassium and niobium, can lead to creation of a number of phases in which the stoichiometry is different than the stoichiometry corresponding to the perovskite, and this has a significant adverse impact on the level of dielectric losses. However, by applying AM technology, KNN remains the most important candidate to replace the lead-containing materials.

The fundamental interaction of AM laser beam and KNN was examined. Thus the laser sintering and welding process was perform to shape different forms of transducers. Laser processing parameters, microstructure, and features of joined layer, are illustrated. The different aspects of the ceramic laser processing from fundamental mechanism up to engineering applicability is discussed.