# Development of Isomorphic Inoculants for Titanium Alloys

**Jacob R. Kennedy** [1,2,3], **B. Rouat** [1,3] ,**D. Daloz** [1,3], **E. Bouzy** [2,3] , **J. Zollinger** [1,3]

[1]*Université de Lorraine, Institut Jean Lamour, Department of Metallurgy & Materials Science and Engineering, Allée André Guinier - ARTEM Campus, F-54000 Nancy, France*

[2]*Université de Lorraine, CNRS, Arts et Métiers ParisTech, LEM3, F-5700 Metz, France*

[3]*Laboratory of Excellence on Design of Alloy Metals for low-mAss Structures (DAMAS), Université de Lorraine, 57073 Metz, France*

*Email: jacob.kennedy@univ-lorraine.fr*

*Email: dominique.daloz@univ-lorraine.fr*

*Email: emmanuel.bouzy@univ-lorraine.fr*

*Email: julien.zollinger@univ-lorraine.fr*

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**Abstract** Ti alloys are particularly interesting for aerospace applications, notably for their specific strength, however, producing parts requires multiple complex processing steps. In the case of Ti-Al alloys in particular their low ductility at room temperature makes them difficult to process. One option to mitigate this is to reduce the size of the grains which form during solidification. Due to the strong burgers orientation relationship between the alpha and beta phases, along with the blackburn orientation relation between alpha and gamma, reducing the size of the solidified beta grains also reduces the size of the grains forming in the solid state. One of the most common methods of grain refinement during solidification is inoculation, the addition of powders to the melt, often ceramics such as TiN or TiB, which act as heterogeneous nucleation sites to form more grains resulting in smaller grain sizes. These powders remain in the material after solidification and unfortunately, as they are often much more brittle than the surrounding matrix, can negatively affect mechanical properties. In order to alleviate this problem, we propose a new technology of inoculation, isomorphic inoculants (ISI). These inoculants are added to the melt in the same manner as traditional inoculants but are engineered to be homogeneous with the matrix after solidification. In order to do this, they must be of the same phase, and have a very small lattice mismatch with the solid forming. A Ti-10Nb-25Al ISI was engineered for use with a Ti-46Al alloy similar to that currently being used to replace Ni based superalloys in the last stage of some aircraft turbines. The solidified grains were reduced in size by up to a factor of 3 with a large increase in the equiaxed fraction of the ingots, as shown in Figure 1a.

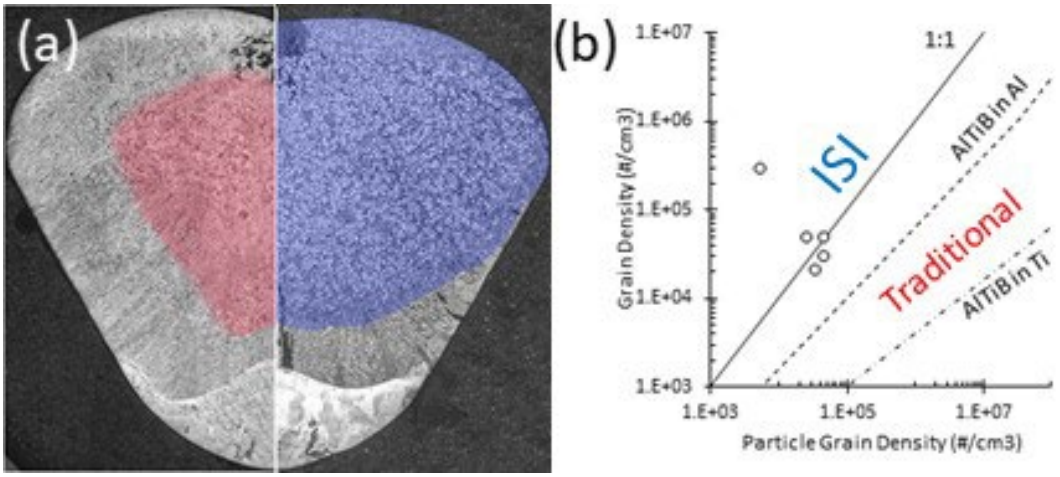


***Figure 1*** *– (a) optical micrograph of reference ingot (left) and ingot inoculated with ISI (right) (b) grain refinement efficiency (number of grains formed by each particle) showing the abnormal efficiency of ISI*

It was calculated that all ISI particles which were present during solidification each formed a grain. Figure 1b shows the stark contrast of this with traditional inoculants, where due to the energy barrier inherent in nucleation, only a small population of the particles added to the melt can act during solidification. Further experiments with Ti64 during additive manufacturing (AM) showed that there is no boundary between the ISI particles and surrounding matrix, they share the same phase and crystallographic orientation. This combined with their high efficiency indicates that the particles act not as heterogeneous nucleation sites, but rather they bypass the nucleation step and act directly as centers of growth during solidification. This has the potential for wide applications in aerospace, both in conventional and AM processing, as refined grains can be formed during solidification without the inherent drawbacks of heterogeneous particles remaining in the solid state.