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# 3D Investigation of the Microstructure Evolution in Hypereutectic Aluminum Silicon Alloy using High Resolution Phase Contrast X-Ray Microscopy

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Contemporary high performance structural materials are being established by their mechanical properties, particularly, the strength, ductility and toughness, corrosion resistance and machinability required for fabricating the devices. However, improving one property often occurs at the expense of other desirable properties. Hypereutectic Al-Si alloy is an attractive class of engineering material that finds application in many critical electronic and defense applications because of its low coefficient of thermal expansion (CTE), high electrical conductivity and light weight as compared to other established alloys. The common problems in all these alloys are inherent brittleness, low formability and catastrophic failure due presence of coarse primary silicon phase and increasing so with the increase in silicon content. In the present work a novel approach by carrying friction stir processing (FSP), a variant of severe plastic deformation process is used for microstructural refinement. The undesirable coarse primary silicon particle (~200 μm) was refined to very small primary silicon particles (~3 μm) via FSP. Also through FSP the particles orientation can be altered such that the preferred directions of the particulates is randomized. The degree to which the modification is achieved can be controlling the number of stir processing passes. The efficacy of FSP is determined by observing the microstructure using optical or scanning electron microscopy techniques where the particulates can be analyzed for shape, size and distribution. However, both these 2D imaging techniques have inherent limitations in which the sub-surface information of the material is not revealed. Knowing the full 3D orientation, shape and distribution plays a key role in better understanding the material. Nevertheless, combining serial sectioning or using focused ion beam milling with optical or SEM techniques can provide the 3D information needed, however both routes are primarily destructive and time consuming.

Here we present results obtained using non-destructive 3D x-ray microscopy for tomography on FSP produced silicon reinforced aluminum matrix composite (Al-30Si). Imaging experiments were conducted using a lab 3D X-ray microscope (Zeiss Xradia 520 Versa) operated in phase contrast mode. Since the x-ray attenuation values of aluminum and silicon are close to each other, the resulting contrast between the two components is significantly lower, and thus poses a challenge when operating in pure absorption mode. To overcome this challenge, we used phase contrast to our advantage by increasing the propagation distance between the sample and the detector, yet, maintaining a high 3D imaging resolution using high magnification objectives in conjunction with geometric magnification obtained by positioning the source and detector appropriately resulting in a 1.35 μm/voxel resolution for this work. The 3D reconstructed datasets from the Al30Si sample showed excellent contrast between the aluminum matrix and silicon particles and clearly resolved 2 -3 μm silicon particles dispersed in the matrix. Along with being able to discern the different sized particles, the images also reveal presence of voids and inclusions. Quantitative analysis was performed by post-processing the data to deduce information on particle volume and distribution. Furthermore, the datasets contain rich information which aid in qualitatively assessing the particles in terms of shape and roughness. We have successfully demonstrated that x-ray microscopy provides an efficient and easy means of non-destructively imaging the material's microstructure in three dimensions, and deriving the essential quantitative parameters that are crucial to controlling process parameters in FSP applied in processing aluminum-silicon alloys.

References

[1] Gan YX et al. Materials 2010, 3, 329-350;
[2] Salih OS et al. Materials & Design Vol. 86, 5, 2015, 61–71.
[3] Tewari A et al. Mater. Sci. Eng., A 2006, 428, 80–90.

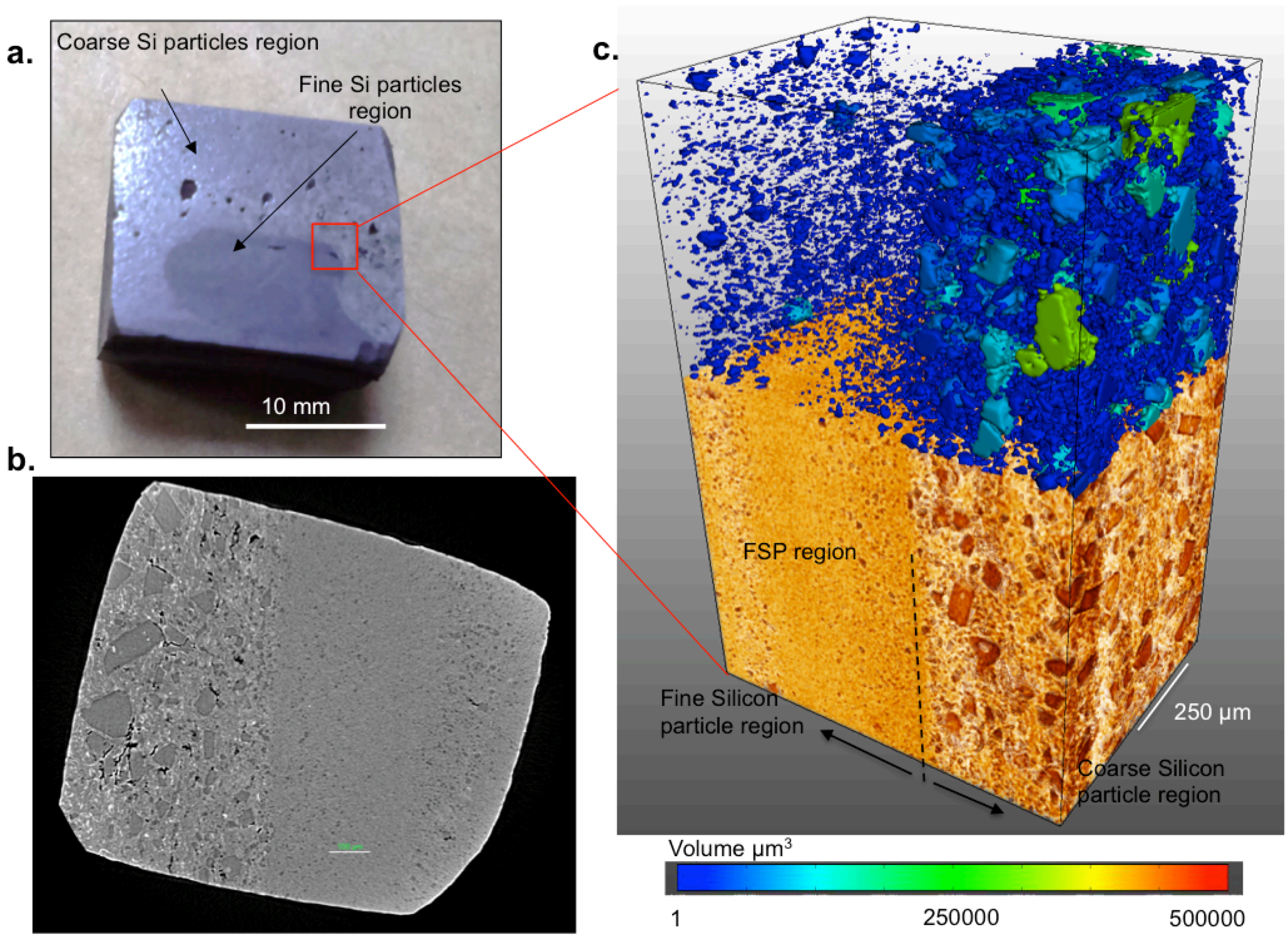


**Figure 1.** (a) FSP produced Al30Si sample with coarse and fine particle Si regions. (b) Reconstructed slice from 3D tomography dataset from Al30Si specimen. (c) 3D volume rendering of reconstructed phase contrast tomography data from Al30Si sample (shown in grey). The 3D volume rendering is overlaid with a surface rendering representing the silicon particle volumes in $\mu m^3$. Distinct regions obtained due to FSP can be seen with modified particle sizes.