# Progress on directional solidification of advanced materials with electromagnetic cold crucible

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**Abstract**：Directional solidification with electromagnetic cold crucible (CCDS) is a newly developed technique, which combines the advantages of electromagnetic cold crucible, directional solidification and continuous melting. It can be applied to directionally solidify reactive, high purity and refractory materials. But there are many difficulties in directional solidification owe to the mass lateral heat transfer that resulting from the water-cooling crucible wall. This paper describes the principle of CCDS and its characteristics; development of the measuring and numerical calculation of the magnetic field, flow field and temperature field in CCDS; and the CCDS of Ti based alloys. The paper overviews original data obtained by some scholars, including the present authors, reported in separate publications in recent years. In Ti based alloys, Ti6Al4V, TiAl alloys and high Nb-containing TiAl alloys have been directionally solidified in different cold crucibles. The cross-sections of the cold crucibles include round, near rectangular and square with different sizes. Tensile testing results show that the elongation of directionally solidified Ti6Al4V can be improved to 12.7% from as cast 5.4%. The strength and the elongation of the directionally solidified Ti47Al2Cr2Nb and Ti44Al6Nb1.0Cr2.0V are 650 MPa/3% and 602.5 MPa/1.20%, respectively. The ingots after CCDS can be used to prepare turbine or engine blades, and are candidates to replace Ni super-alloy at temperatures of 700 to 900 ºC. A square cold crucible with the inner size of 60mm×60mm, appropriate for continuous melting and directional solidifying silicon was designed and fabricated. It is found that increasing the input power, pulling velocity and decreasing the heat preservation time will result in the solid/liquid interface change from convex to planar, and then to concave gradually, and the grain size decreases. In 6N silicon ingot, as compared with the ingot that cast by conventional directional solidification, the oxygen content is much lower, the carbon content and resistivity are at the same level, both of them are controlled in the effective range, the minority carriers lifetime is higher than that of the raw materials and slightly lower than that of the conventional directinoal solidified ingot.
Different Nb-Si alloys have been successfully directionally solidified by electromagnetic cold crucible. In the alloy of Nb–22Ti–16Si–3Cr–3Al–2Hf (at.%) , the microstructures were composed of primary Nbss, Nbss + α-(Nb, Ti)5Si3 eutectic and Nbss + Ti-rich (Nb, Ti)5Si3 eutectic. With the increase of withdrawal rate, the microstructure became finer, the high temperature tensile strength increased gradually. The more number of Nbss/(Nb, Ti)5Si3 interfaces was conducive to impeding the movement of dislocation, which caused the

improvement of tensile strength. Nb–24Ti–12Si–4Cr–4Al–2Hf (at%) has been successfully fabricated by electromagnetic cold crucible. Compared steady-state growth region with initial transition zone, the room temperature fracture toughness and the high temperature tensile strength increased about 50% and 24%, respectively, which was contributed to the directional solidification microstructure and the type transformation of silicide.

Keywords: electromagnetic cold crucible; directional solidification; TiAl; multicrystalline silicon; Nb-Si