4.3 ELECTRON-BEAM ADDITIVE MANUFACTURING OF TUNGSTEN MATERIALS FOR FUSION — E. K. Ohriner, R. Dehoff, and L. L. Snead (Oak Ridge National Laboratory)

OBJECTIVE

The objective of this work is to produce graded tungsten-iron layers on a steel substrate using the ARCAM electron beam melting (EB) additive manufacturing system now under development at ORNL.

SUMMARY

Initial experiments were performed with the ARCAM A2 electron beam additive manufacturing unit using standard beam deflection conditions. Local regions were observed with the desired microstructure of a solid tungsten surface layer and a liquid phase sintered boundary layer of tungsten particles in a steel matrix. A new ARCAM unit is currently being installed for use in future experiments.

PROGRESS AND STATUS

Single layers of tungsten powder of from 0.8 and 1.6 mm thick have been deposited on steel and EB melted. A steel coupon with melted tungsten powder is shown in Fig. 1. Tungsten powder bed depths of about 1 mm result substantial melting of the steel substrate. A powder bed depth of 1.6 mm resulted in melting of the top surface of the tungsten powder bed, no melting of the steel substrate, and little adherence of the melted tungsten layer to the steel. A powder bed depth of 1.4 resulted in a nearly continuous fully melted tungsten powder with a porous subsurface region of liquid phase sintered tungsten particles in a steel matrix. A powder bed depth of 1.2 mm produced in some local areas with the desired microstructure of a surface layer of essentially pure tungsten bonded to the steel substrate by a subsurface layer of steel infiltrated tungsten particles (Fig 2.)

Since the melting is accomplished by deflection of the electron beam across the surface of the powder bed in an arbitrary and non-optimal pattern, the melting of the surface is not uniform. An example of this can be seen in Fig. 3 on the surface of a melted tungsten powder layer of 1.4 mm thickness. It is increasingly apparent that a much more sophisticated beam deflection pattern that accounts for thermal cycles, with localized in-process changes in thermal conductivity, is needed to obtain consistent uniform surface layers with the desired structure such as in Figure 2.

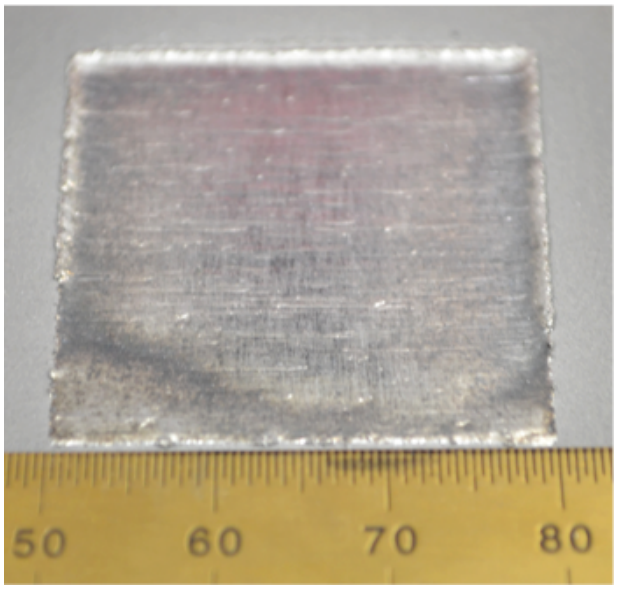

Fig. 1. Melted tungsten powder incorporated into H-13 steel coupon.

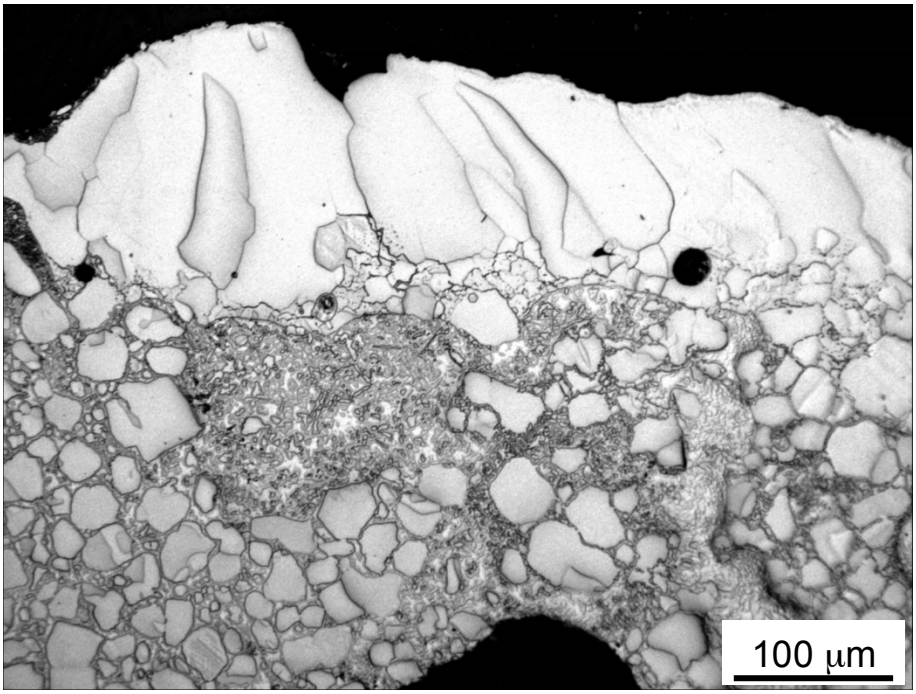

Fig. 2. Cross-sectional view of melting with powder bed depth of 1.2 mm shows a local area of continuous fully melted layer of tungsten powder, at top, bonded to the steel substrate by an intermediate layer of tungsten particles (light contrast) infiltrated by steel (dark contrast).

Fig. 3. Surface view of melting with powder bed depth of 1.4 mm shows pattern of fully and partially melted areas associated with the pattern of beam deflection across the sample surface.