N89-13659 517-27 181385 8P.

# MICROLAMINATE COMPOSITES - AN ALTERNATE APPROACH TO THERMAL BARRIER COATINGS

R.F. Bunshah, C.V. Deshpandey, and B.P. O'Brien
University of California
Department of Materials Science and Engineering
Los Angeles, California 90024

Ceramic thermal barrier coatings suffer from a major drawback - i.e., brittle behavior. An alternate approach is microlaminate composite coatings consisting of alternate layers of metal and oxide. As the thickness of the individual laminae decreases while keeping the total thickness of the coating constant, the thermal conductivity drops markedly. Data on the Fe-Cu system will be presented. A model is proposed for an MCrAlY-$Al_2O_3$ microlaminate coating for thermal barriers. The methods of fabrication will also be discussed.

## OBJECTIVE

To demonstrate the potential for low thermal conductivity microlaminate composites as an alternate to bulk ceramics.

Advantage: Improved fracture toughness at equivalent thermal conductivity.

## MICROLAMINATE COMPOSITES

Bulk mateiral or coatings upto 0.040" thickness consisting of alternate layers of different materials.

## MATERIAL COMBINATIONS STUDIED

Metal-Metal: Fe-Cu, Ni-Cu, Ti-Ni, Co-Cu
Metal Ceramic: Ni-TiC, MCrAlY-$Al_2O_3$
Ceramic-Ceramic: $TiC/TiB_2$

## METHOD OF PREPARATION

. Electron beam evaporation from metal or ceramic sources.

## DEPOSITION RATE

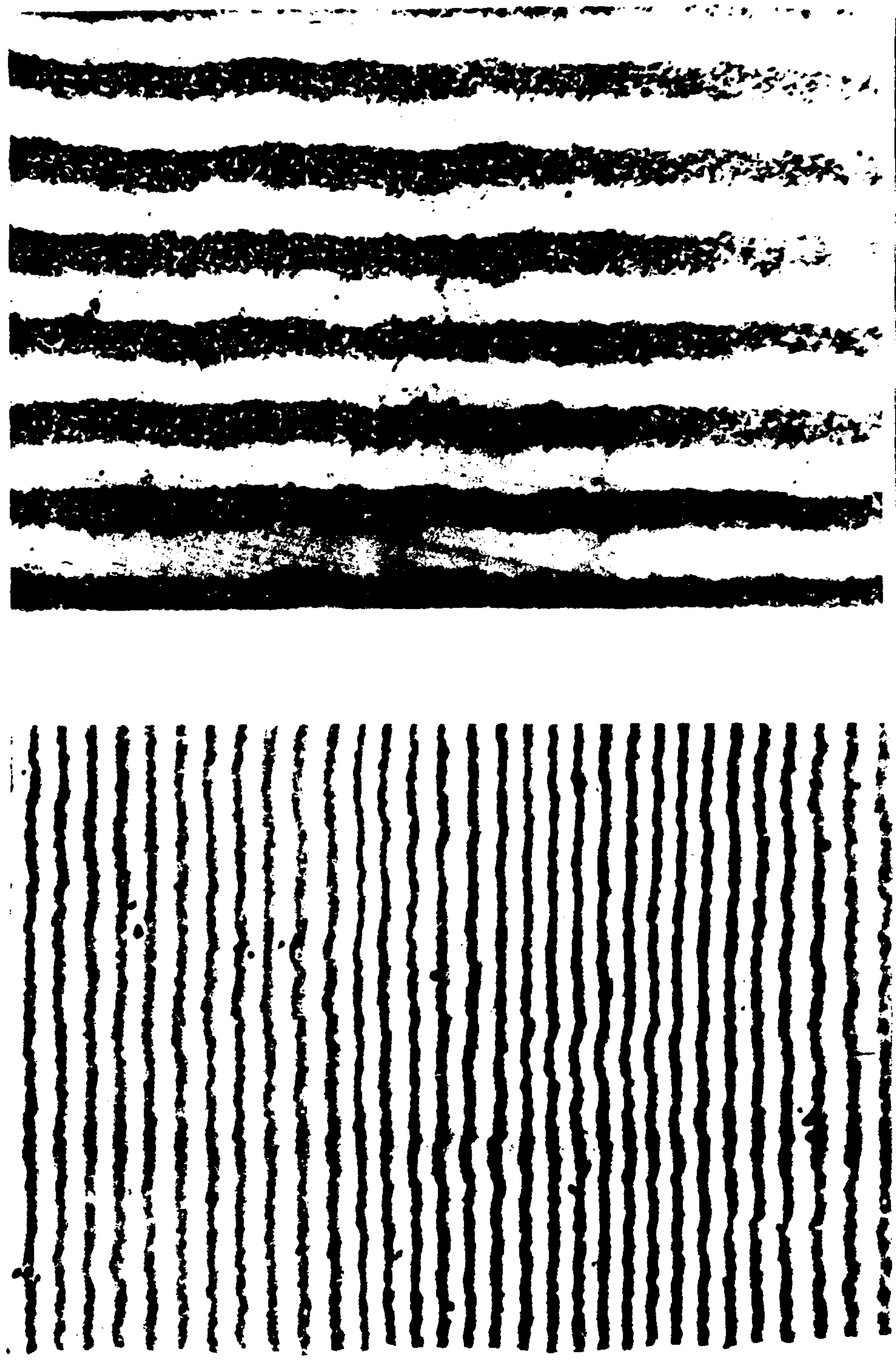
Upto 10 $\mu$m per minute

## LAMINATE THICKNESS

1 m to 40$\mu$m

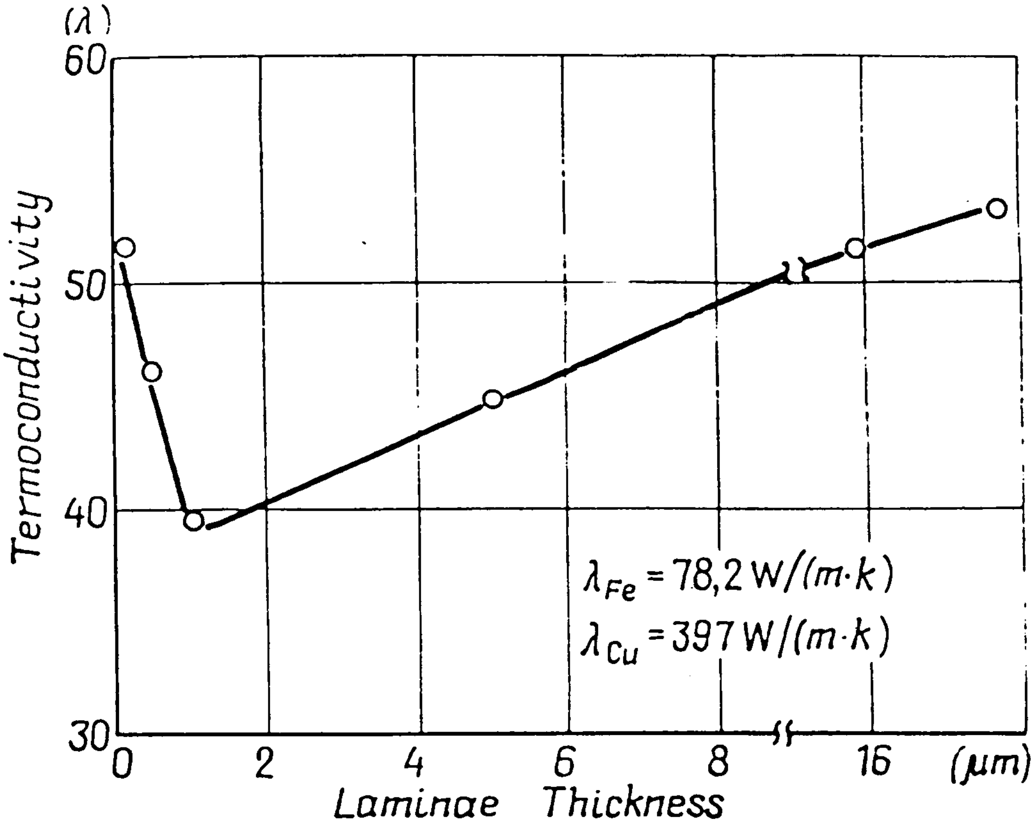
## PROPERTIES STUDIES

Strength, ductility and thermal conductivity



Electron micrographs of "MCrAlY" microlaminate prepared using electron beam evaporation thickness 2 m( by Movchan et. al. at Paton Institute, USSR.

Shown in the figure below is the thermal conductivity (perpendicular to laminae plane) of Fe/Cu condensates as a function of laminae thickness. The total thickness = 40 mils (1000$\mu$m)






C-3

It should be noted that thermal conductivity of the condensate is much lower than could be expected from simple rule of mixtures. For this particular case the value would be 238 w/km, if calculated using the rule of mixtures.

This drop in thermal conductivity is believed to be associated with interfaces which in some way block the transfer of heat across it. Considering this assumption the expression for thermal conductivity of the microlaminate can be written as

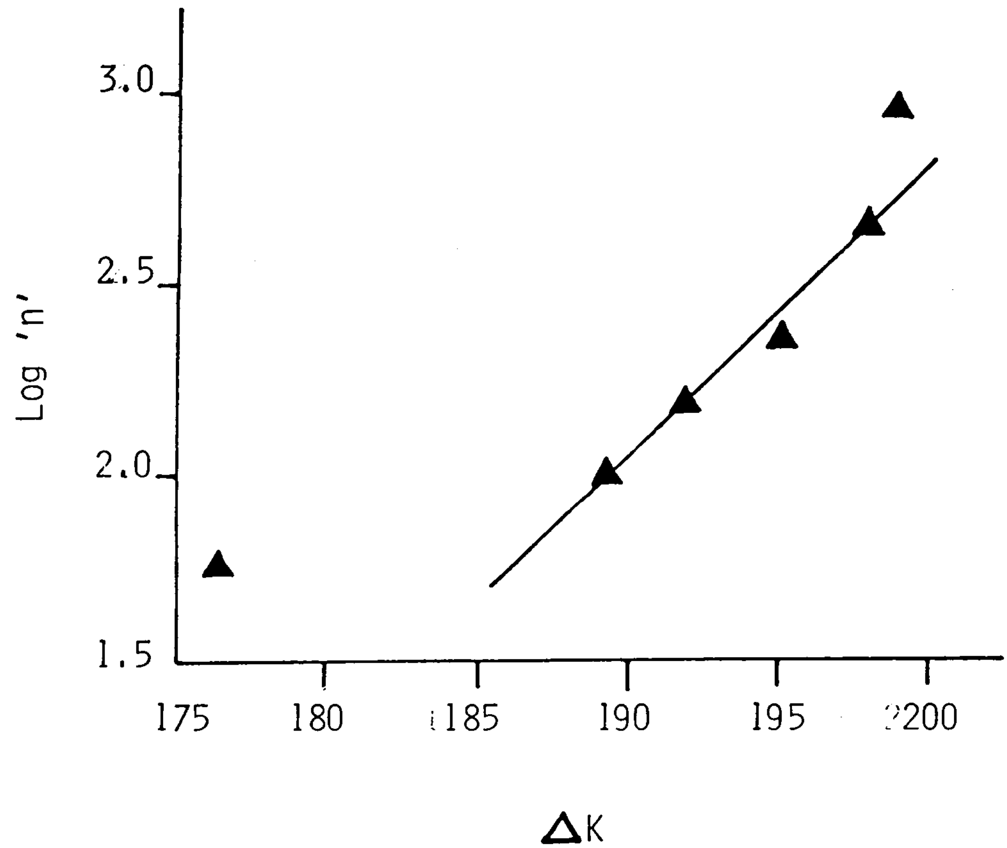
$$K = V_{f_{cu}} \cdot K_{cu} + V_{Fe} \cdot K_{Fe} + n_I \cdot K_I \qquad (1)$$

where $V_f$ is the volume fraction, K the thermal conductivity and $n_I$ is the number of interfaces given by the expression

$$n_I = t/_{\Delta x} - 1 \qquad (2)$$

where t is the laminate thickness and $\Delta x$ is the laminae thickness.

Using Equations 1 and 2, and the data shown in Figure 1, contribution of interfaces to the thermalconductivity is calculated. Shonw in the figure below is the thermal conductivity contribution due to interfaces as a function of the number of interfaces.



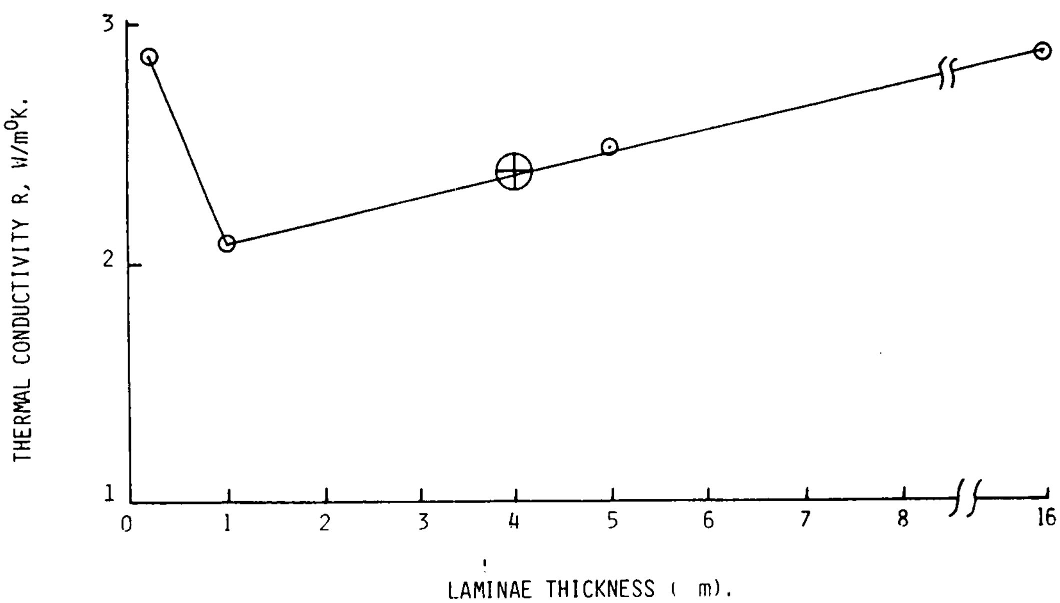

It can be seen that the data can be fitted into an expression of the form

$$n_I = A \exp^{-\Delta K_C}$$

Where c is the slope of the plot Log $n_I$ Vs $\Delta K$ and A is a constant

The constant 'A' should account for the materials characteristics and types of phonon scattering mechanisms involved at the interfaces. Detailed investigations are required to establish a qualitative expression for 'A' in terms of materials properties and phonon scattering modes.

However assuming that the interfaces would behave in the same manner as in case of Fe-Cu microlaminate we have calculated assuming the same percentage contribution by the interfaces, the thermal conductivity of MCrAlY/$\alpha$-$Al_2O_3$ microlaminate. The data is plotted in the figure below.




Thermal Conductivity (direction ⊥ to laminae plane) vs. laminae thickness for MCrAlY - $\alpha Al_2O_3$ microlaminates.

In practice 15 mils of $ZrO_2$ coating is used as thermal barrier coating. For 15 mil thickness and 1$\mu$m laminae thickness the number of interfaces would be 224. The thermal conductivity of a laminate with these many interfaces would be equal to 2.38-2.4 w/mk. This value is comparable to the thermal conductivity of pure $ZrO_2$ coating which is 3 w/mk.

These simple calculations therefore indicate that microlaminate composites offer as excellent potential as thermal barrier coatings.

## PROPOSED FABRICATION TECHNIQUE

Electron beam evaporation/deposition alternately from two sources onto superalloy substrates (see Figure). This is compatible with current MCrAlY deposition methodology.

## PROPERTIES TO BE MEASURED

Thermal Conductivity

Fracture Toughness - Using an indentation method (Evans et al., J. A. P. 53, 312, 1982).

Properties to be measured as deposited and after thermal cycling.

## CONCLUSIONS

Microlaminate composites offer the potential to be a low thermal conductivity high fracture toughness material to be used as a thermal barrier coating on superalloy blades and vanes as an alternate to monolithic ceramic coatings.