HENRY ROYCE INSTITUTE
ADVANCED METALS PROCESSING

ROYCE@SHEFFIELD INDUSTRY COLLABORATION

MAKING BETTER BRAZING ALLOYS FOR USE IN THERMOELECTRIC MATERIALS

Researchers from The University of Sheffield are helping to harvest energy from waste heat in transport, by tackling a fundamental manufacturing challenge

Brazing is a metal joining method with several unique advantages. By introducing a low melting point alloy filler, separate materials can be joined to create products or devices with customised properties. When heated, the alloy will melt, flowing between the different materials and forming a bond. The primary benefit of brazing is the ability to join dissimilar materials, taking advantage of their unique characteristics to create an ideal product for a particular application. For example ceramics can be joined with some metals using this method to create a stronger more durable product.

CHALLENGE

Thermoelectric materials are ceramic-based, functional materials. By creating a temperature difference across them they can create electric currents, meaning they can be used to harvest energy from waste heat. Imagine putting one of these in a car exhaust; there are a number of constraints that need to be considered. The materials need to be conductive and operational at the temperature of the car exhaust (100 - 500 °C). Joining a ceramic to a metal is already a difficult process; it cannot be welded, and cannot be glued as adhesives are ineffective at above 200 °C, and they are not very conductive. Brazing is one of the only techniques that will fulfil the necessary requirements.

We begin with silver-based brazing alloys which require a temperature of around 700-800 °C to work. However, if the materials are heated too much, the thermoelectric properties will be destroyed as they do not survive at elevated temperature (for some thermoelectrics this can be 500 or 600 °C. This is a narrow window not well served by current materials or technologies.

OPPORTUNITY

We have been working with a concept known as high-entropy alloys for a number of years now. This differs from typical alloying and involves mixing together different elements in very similar quantities. The difficulty in high-entropy alloying is the ability to predict which materials will have a successful outcome.

For example, if an application requires a silver material but with a low melting point, then adding a small amount of different elements may be beneficial. If five separate elements are introduced, this will result in over half a million different materials combinations. When accounting for variability in amounts for each different combination, there become millions of different alloys to test. However, by utilising a computational approach with set parameters we are able to predict the success of alloy brazing for different materials.

The next stage is selecting the best options and creating the alloys themselves. Using the Royce arc and induction melting equipment

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at the University of Sheffield we physically form between five and ten alloys and characterise them using microscopes and x-ray diffraction. The unique benefit of the Royce equipment is the ability to make up a vast range of different alloys rapidly with direct access to the equipment, without the need to have a contract with an external supplier. The ability to do the modelling and the predictions, and then next-door being able to see that it works, that's a very powerful coupling.

RESULTS

Using this method, we have tested new formulations with some low melting point elements with positive results. We have managed to fulfill the list of requirements in terms of the operation temperature and the different materials that need to be joined. Our industry partner is currently considering IP protection for this range of alloys.

For a brazing metal producer a successful outcome for this research is a new product line, potentially in a new business area. For the thermoelectric users and suppliers, the ability to join their products to other materials in a way that is simple and robust, and doesn't need exceptionally tight process control to make sure they don't damage the thermoelectric is extremely beneficial.

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