Fabrication of high thermal dissipation composites by ultrasonic mechanical coating and armoring

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Abstract

In this study, a mechanical plating method was used to produce high emissivity coatings on 1050 aluminum substrate by adding powders into the surface layer. This method is called UMCA (ultrasonic mechanical coating and armoring). Aluminum alloys often have high thermal conductivity but poor infrared emissivity. High emissivity coating is often fabricated on the substrate to decrease the surface temperature by radiation. We attempt to make high thermal dissipation efficiency composite by coating ceramic powders on 1050 aluminum substrate using UMCA technique. Different powders were chosen in this work, the cooling test reveal that dissipation efficiency has great dependence on the coating materials and the thickness.

RESULTS

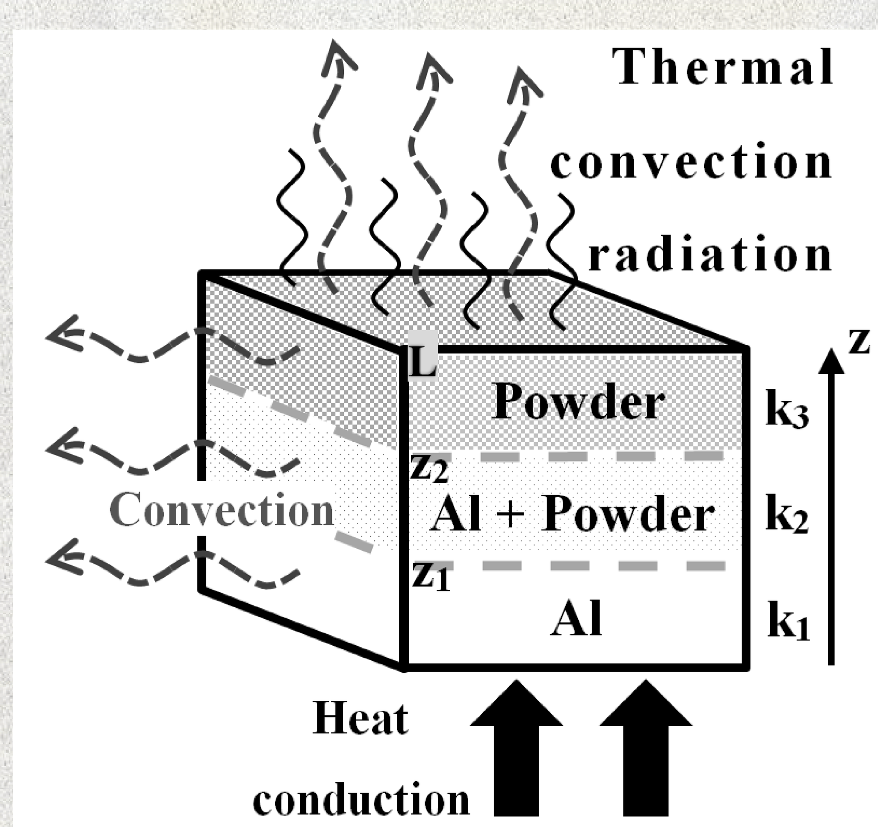
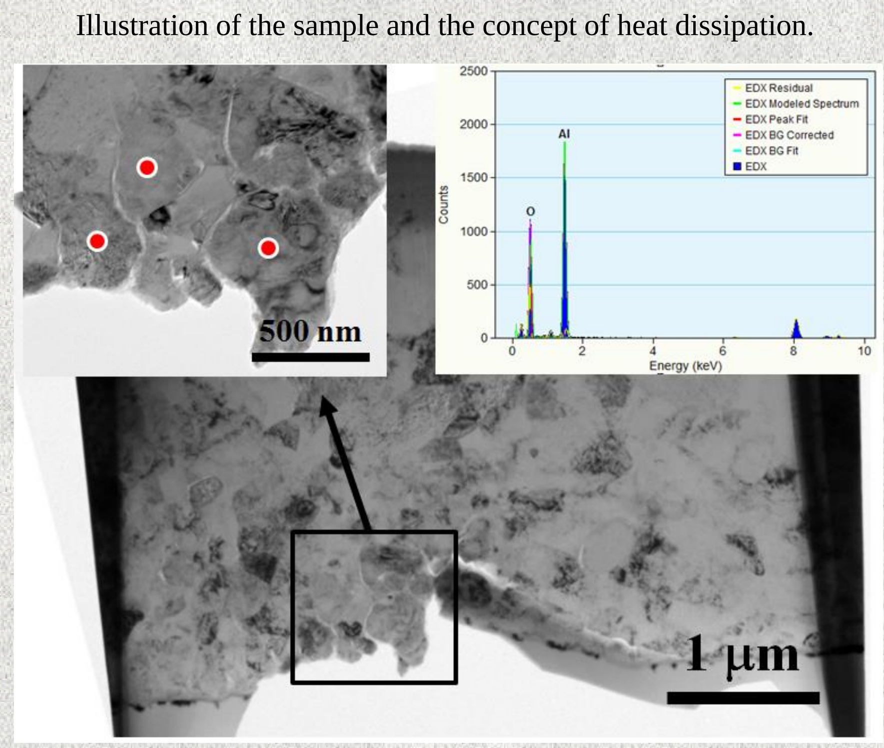
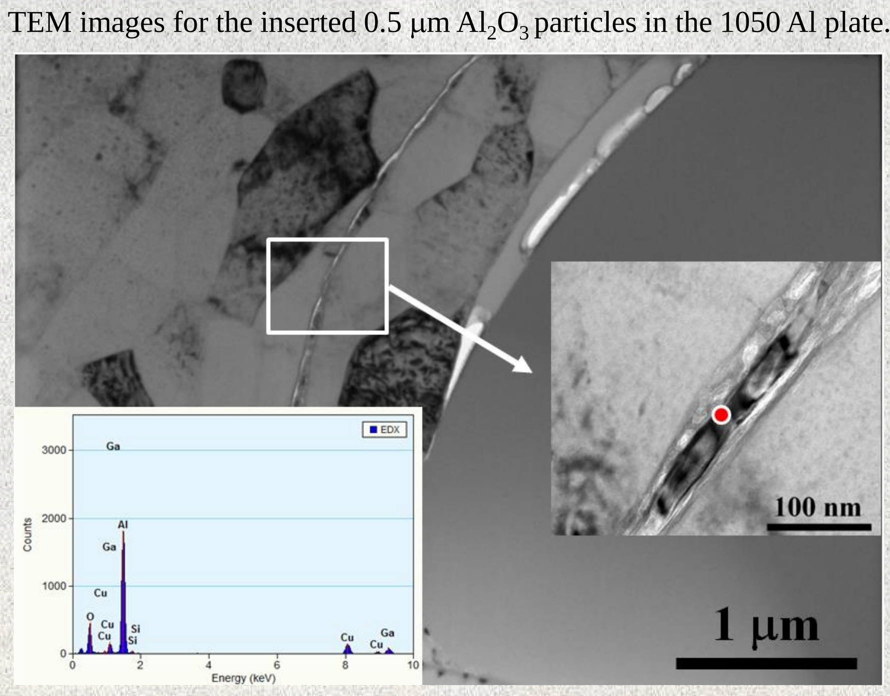


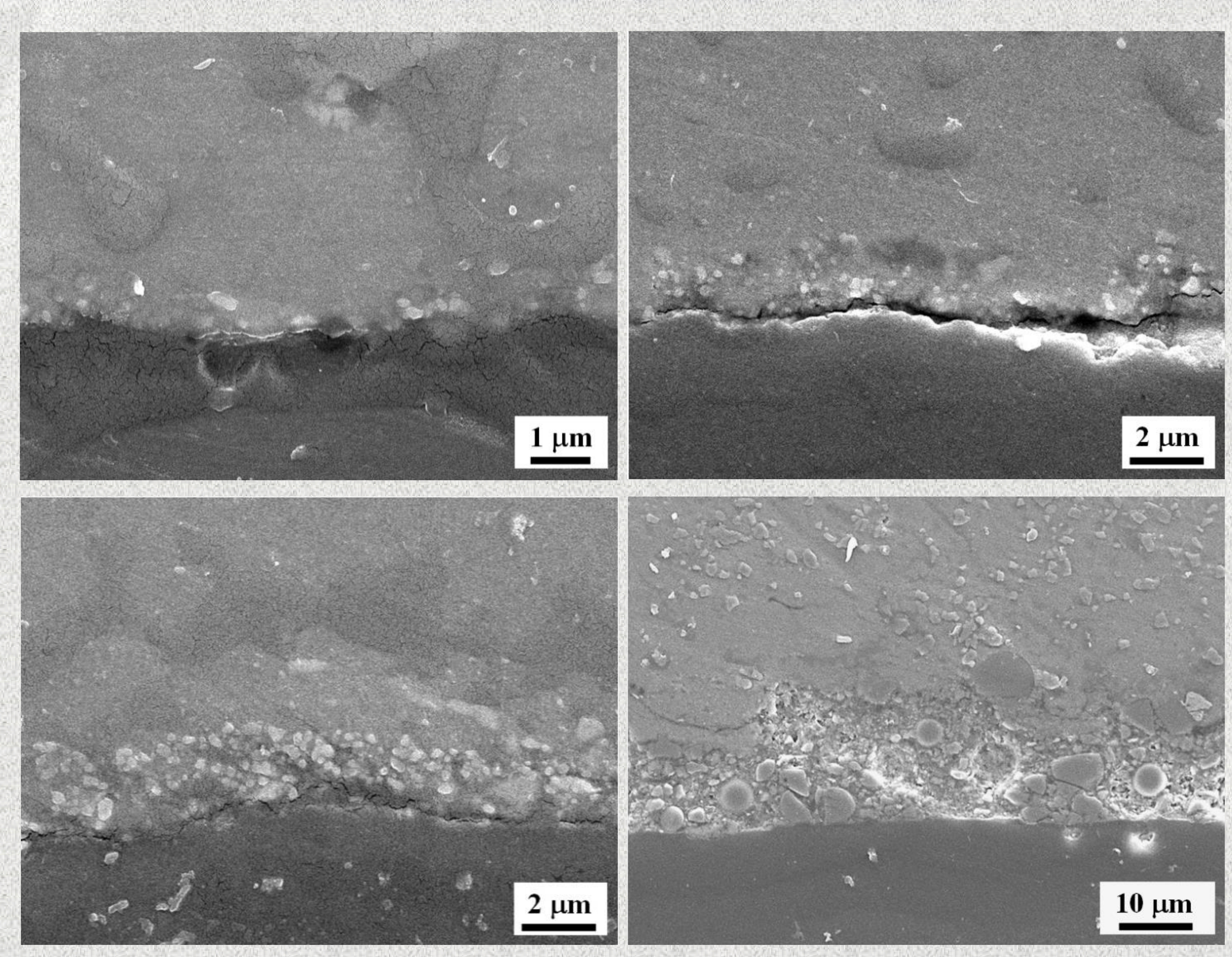
Illustration of the sample and the concept of heat dissipation.



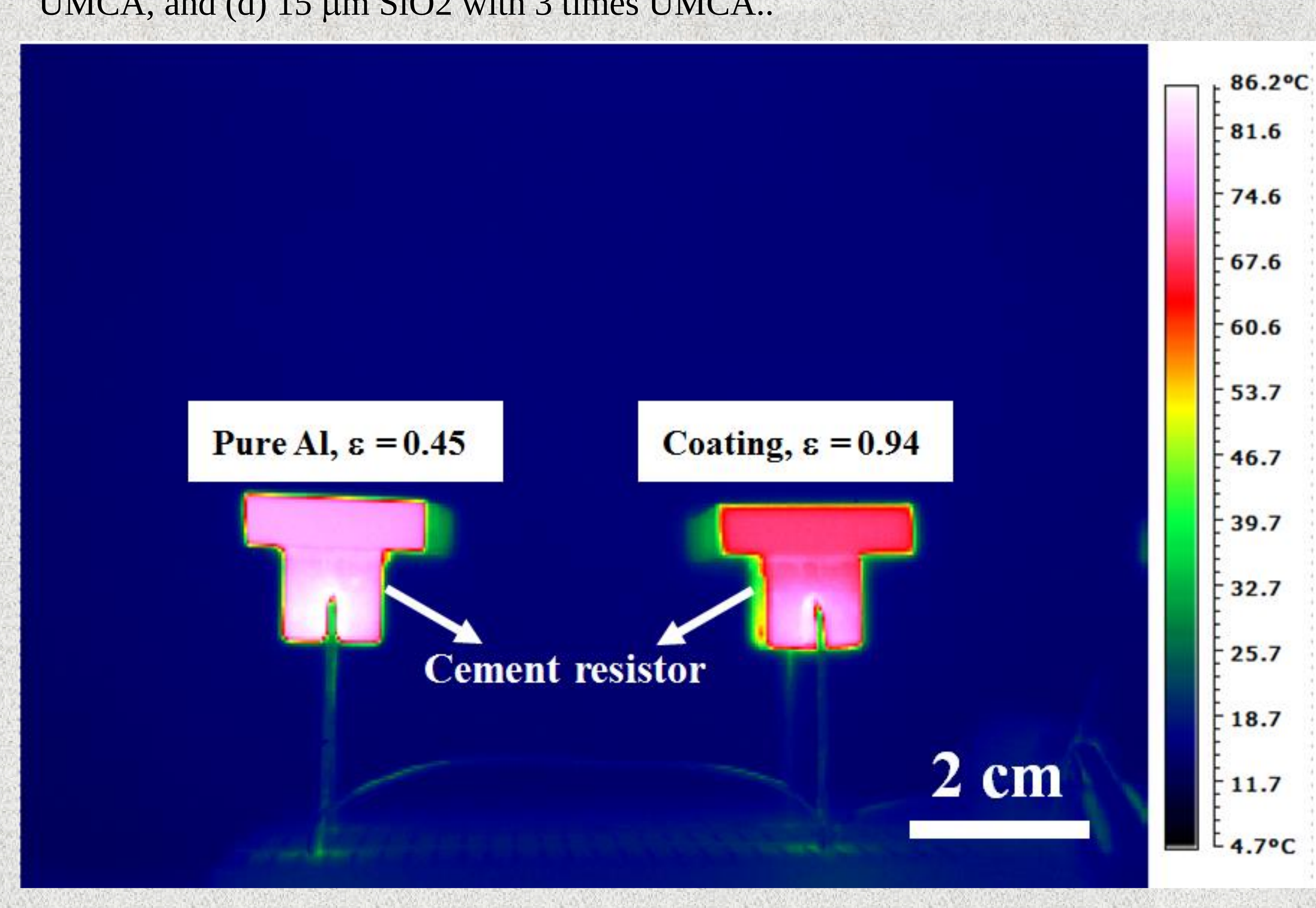
TEM images for the inserted 0.5 µm Al_2O_3 particles in the 1050 Al plate.



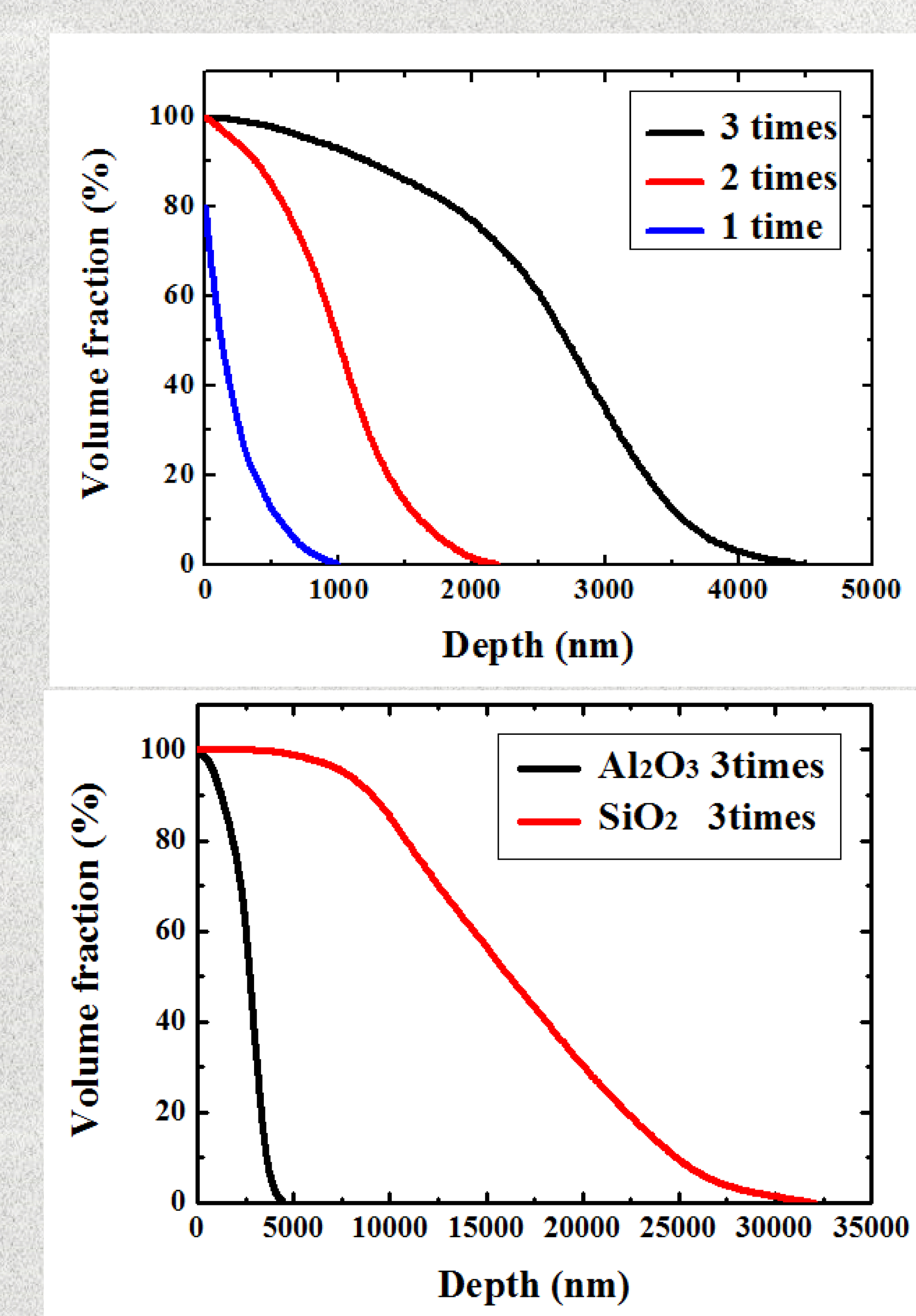
TEM images for the inserted 20 µm SiO_2 particle in the 1050 Al plate.



Typical cross-sectional SEM micrographs taken from samples: (a) 0.5 µm Al2O3 with 1 time UMCA, (b) 0.5 µm Al2O3 with 2 times UMCA, (c) 0.5 µm Al2O3 with 3 times UMCA, and (d) 15 µm SiO2 with 3 times UMCA..



The setup of the thermal dissipation test under infrared imaging. The uncoated Al sample is shown on the left and the mechanically coated Al (this time with Al_2O_3 + SiO_2) is on the right. The Al samples are placed above the cement resistor connected with the power supply.



Representative inserted particle distribution in the Al matrix: (a) for the 0.5 µm Al_2O_3 particles after UMCA for 1-3 cycles, (b) for 0.5 µm Al_2O_3 and 15 µm SiO_2 particles after 3-time UMCA.

Coating	Q (W)	ΔT (°C)
Al_2O_3+SiO_2 3L	1.08	2.5
Al_2O_3+SiO_2 3L	1.66	3.9
Al_2O_3+SiO_2 10L	1.66	7.7
Graphite 3L	1.08	3.4
Al_2O_3+SiO_2+Graphite	1.66	8.0
CNT+Al_2O_3 Sol-Gel	1.66	10.6
CNT+Al_2O_3 Sol-Gel	2.4	13.2
Shot peening	1.66	3.7
Etched by NaOH	1.66	0.2

Summary of dissipating effects for different coating.

Conclusions

1. By the transfer of kinetic energy from steel balls onto the pre-coated material, those ceramic powders can be implanted into the target substrate.
2. The small sub-micron 0.5 µm Al_2O_3 particles are nicely and uniformly doped by UMCA into the Al matrix with no apparent gap or second phase generated. However, some interface gaps would be inevitably formed between the ceramic particles and Al matrix in the cast using 10-20 µm powders.
3. The dissipation efficiency has great dependence on the coating materials and the thickness.
4. By coating adequate emissive powder on the metal substrate, the overall dissipation effect can be eminently elevated.