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The effect of strong and weak interfaces on thermophysical properties of metal matrix composites reinforced with high modulus and high thermal conductivity C fibres – K 1100

K. Izdinsky, P. Stefanik, F. Simancik, N. Beronska, T. Dvorak, S. Kudela, J. Korab

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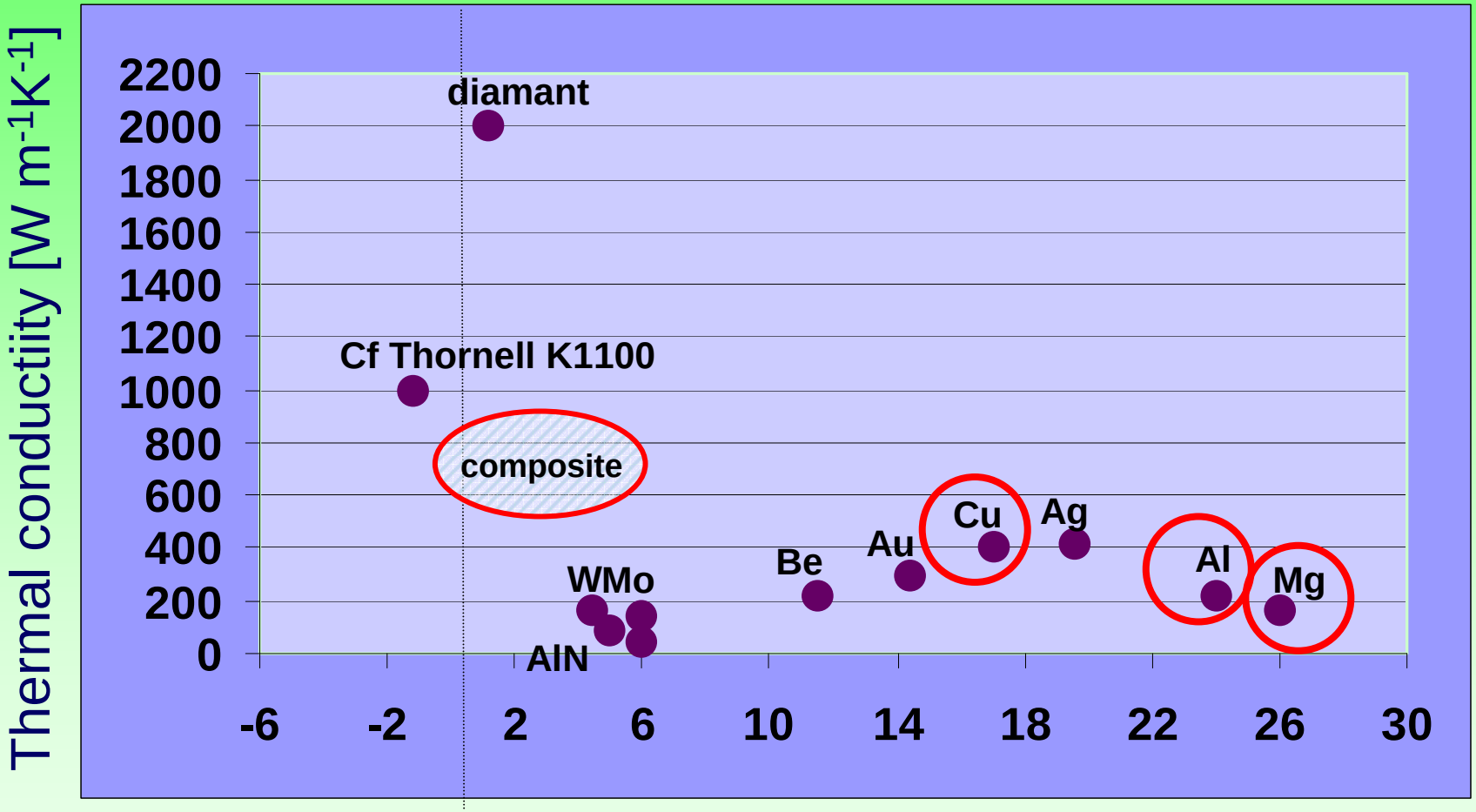

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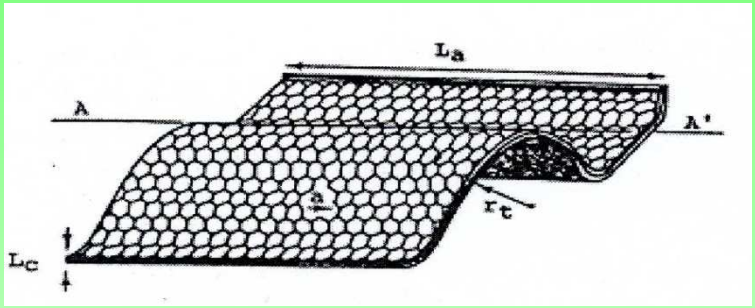
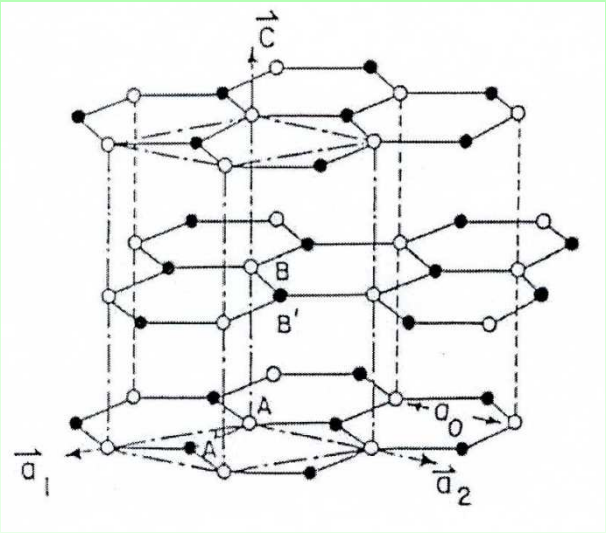
Thornel K1100 carbon fibre





Tensile strength [GPa]	3.10
Tensile modulus [GPa]	965
Density [kg/m^3]	2200
Filament diameter [µm]	10
Carbon Assay [%]	99+
Surface Area [m^2/kg]	400
Electrical Resistivity [µΩ.m]	1.1 – 1.3
TC in longitudinal direction [W m^{-1} K^{-1}]	**900 - 1000**
TC in transversal direction [W m^{-1} K^{-1}]	**2.4**
Longitudinal CTE at 21°C [10^{-6} K^{-1}]	**- 1.5**
Transversal CTE at 21°C [10^{-6} K^{-1}]	**12.0**

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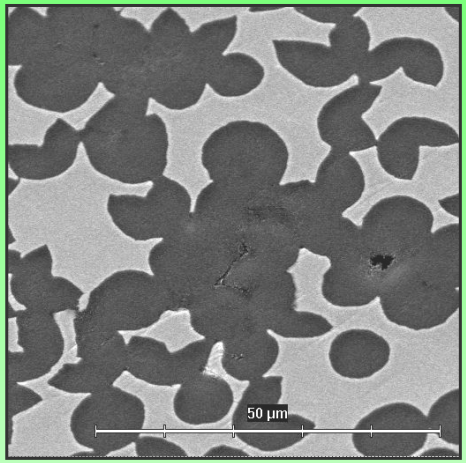
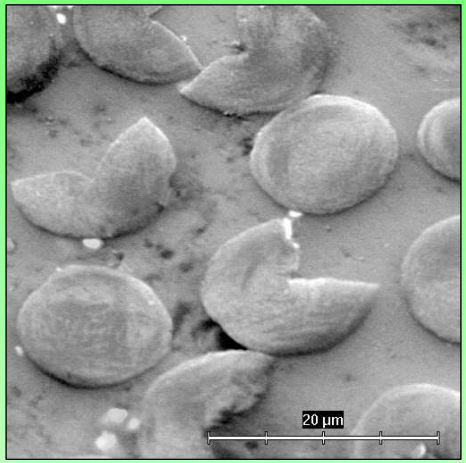
Cu-C composite –
- no wetting
- no reaction



Mg-C composite
– no wetting
- no reaction with

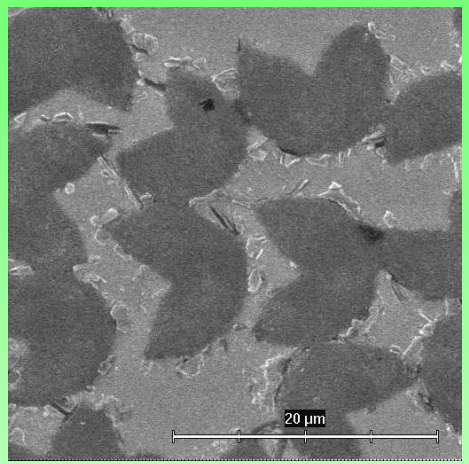


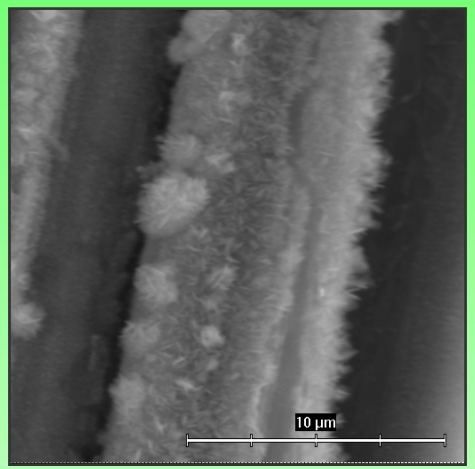
alloy	carbide	temperature	contact angle
		[°C]	[°]
Cu	**Cr_3C_2**	1100	**47**
Cu	**Cr_3C_2**	1150	**44**
Cu	TiC	1100-1200	112-109
Cu	ZrC	1100	135

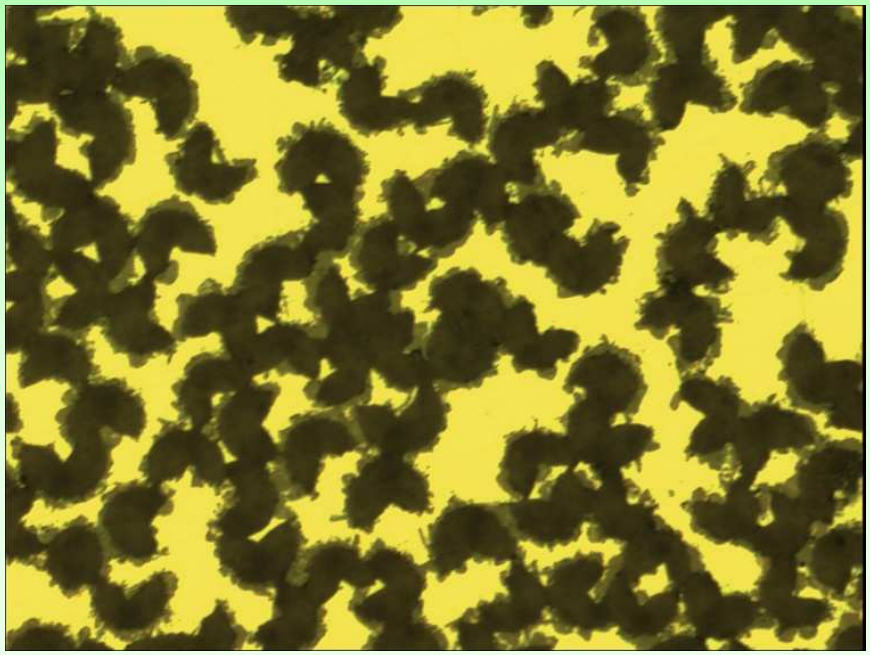
For both systems the improvement of interfacial bonding is a necessity

in Cu-C composite by alloying with Cr
in Mg-C composite by alloying with Al

Al-C composite –
strong interfacial reaction that
needs to be avoided

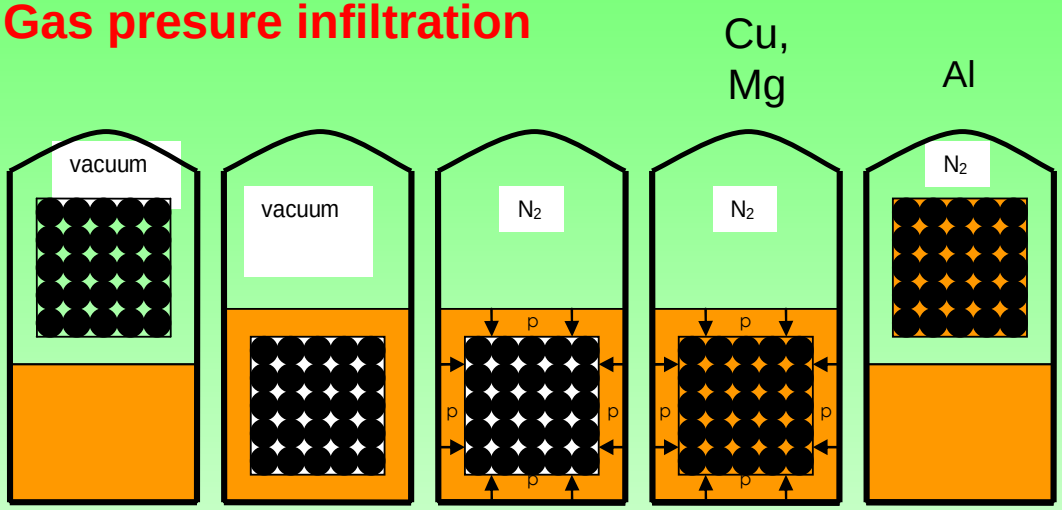




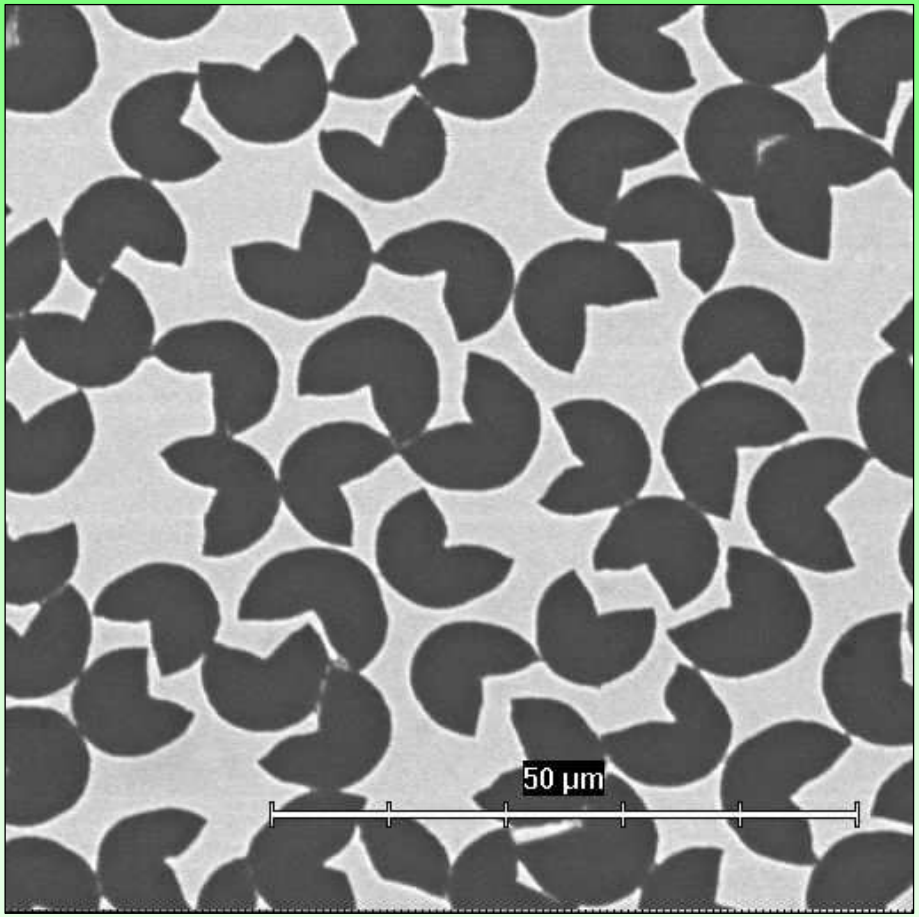


Alloying of Al with surface active element
Mg was adopted

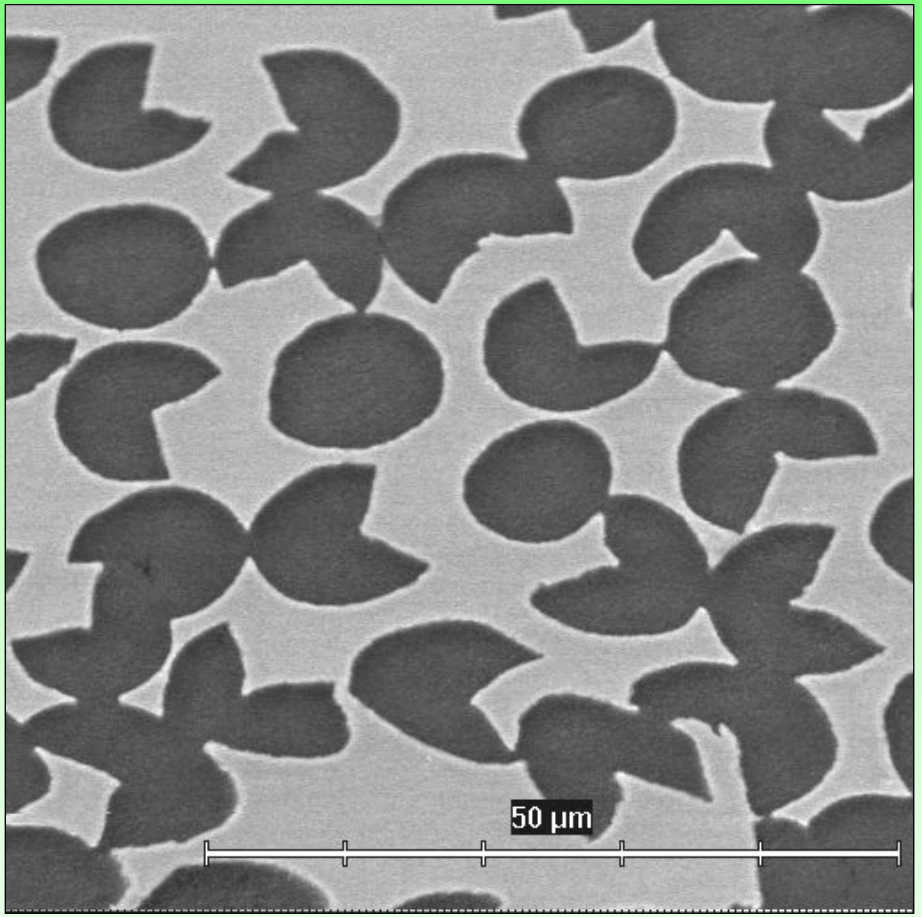
Gas presure infiltration



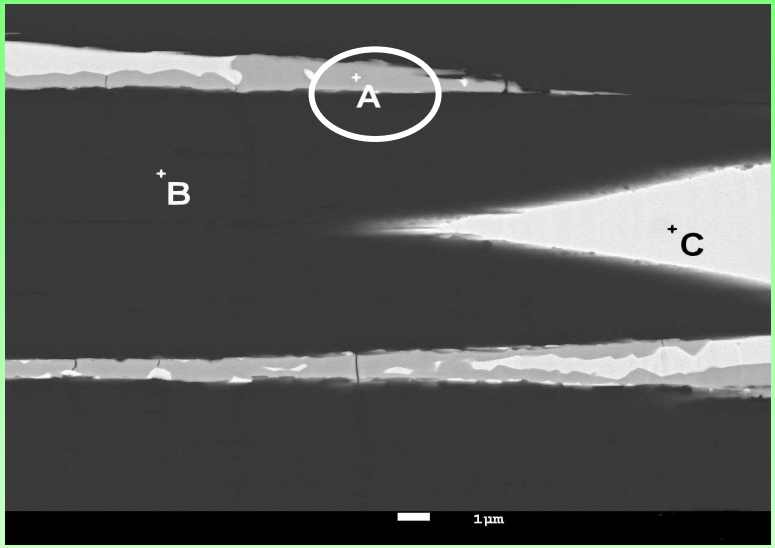
Infiltration parameters	Cu-C	Al-C	Mg-C
Temperature [℃]	1200	750	730
Time [s]	300	120	300
Pressure [MPa]	6	5	8

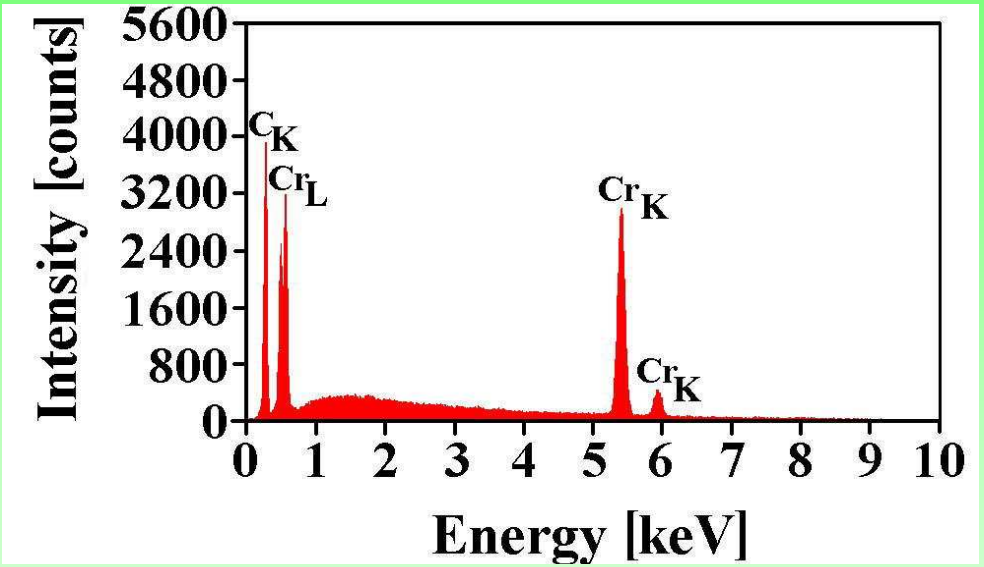


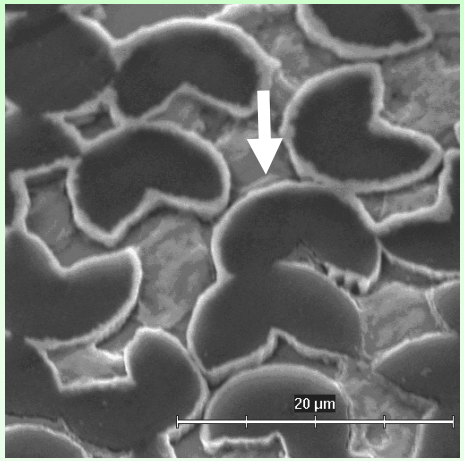
Structure of Cu0.2Cr-K1100 composite

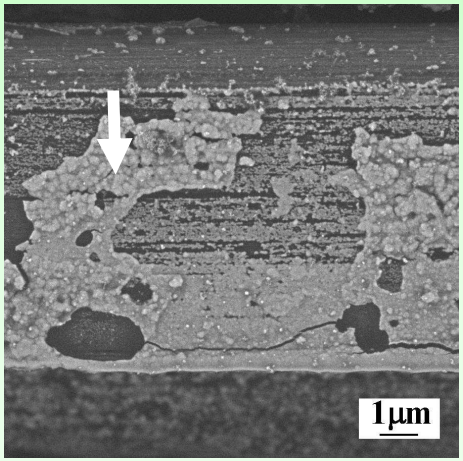


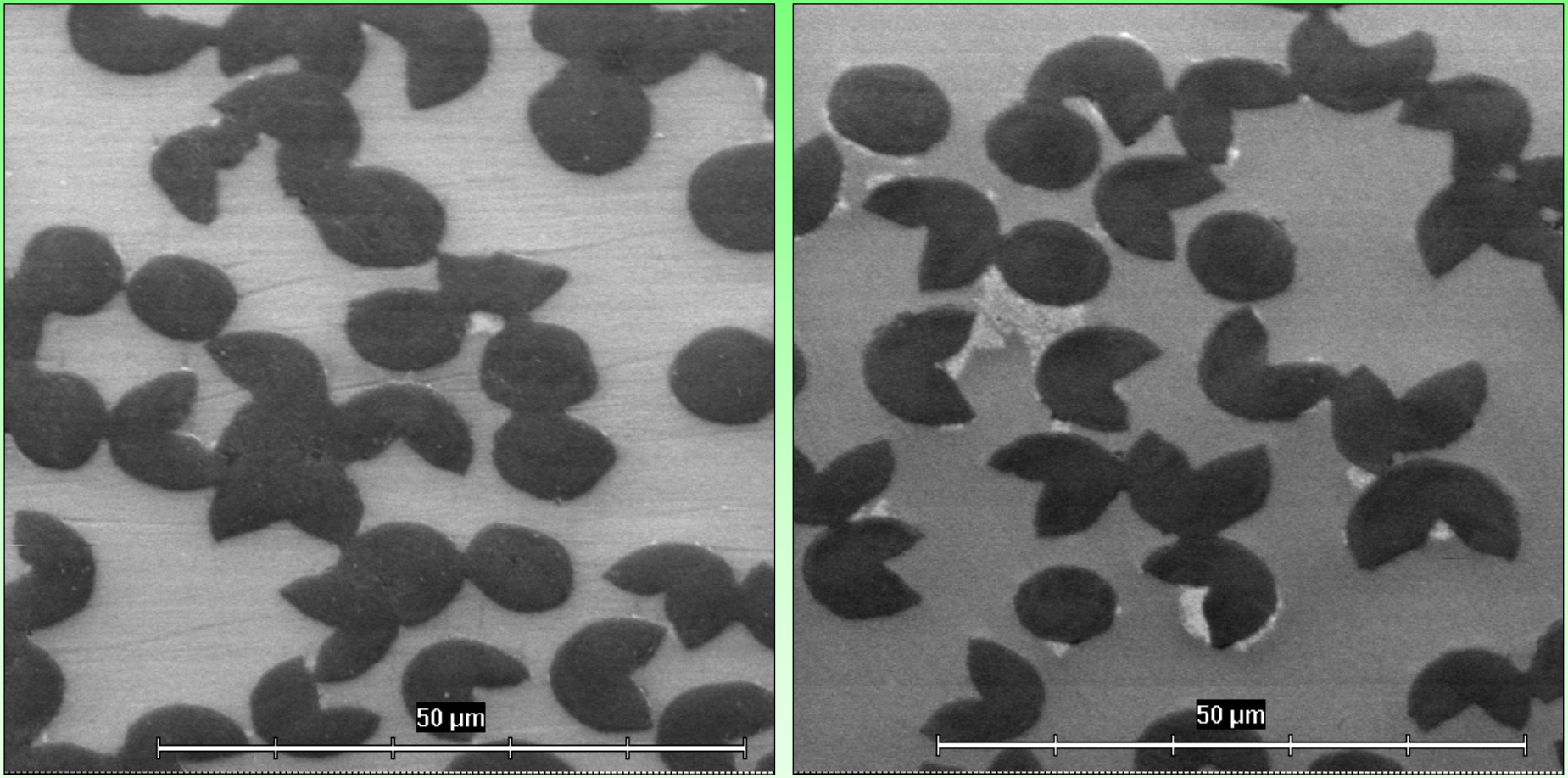
Structure of Cu1Cr-K1100 composite


A
B
C
1 µm

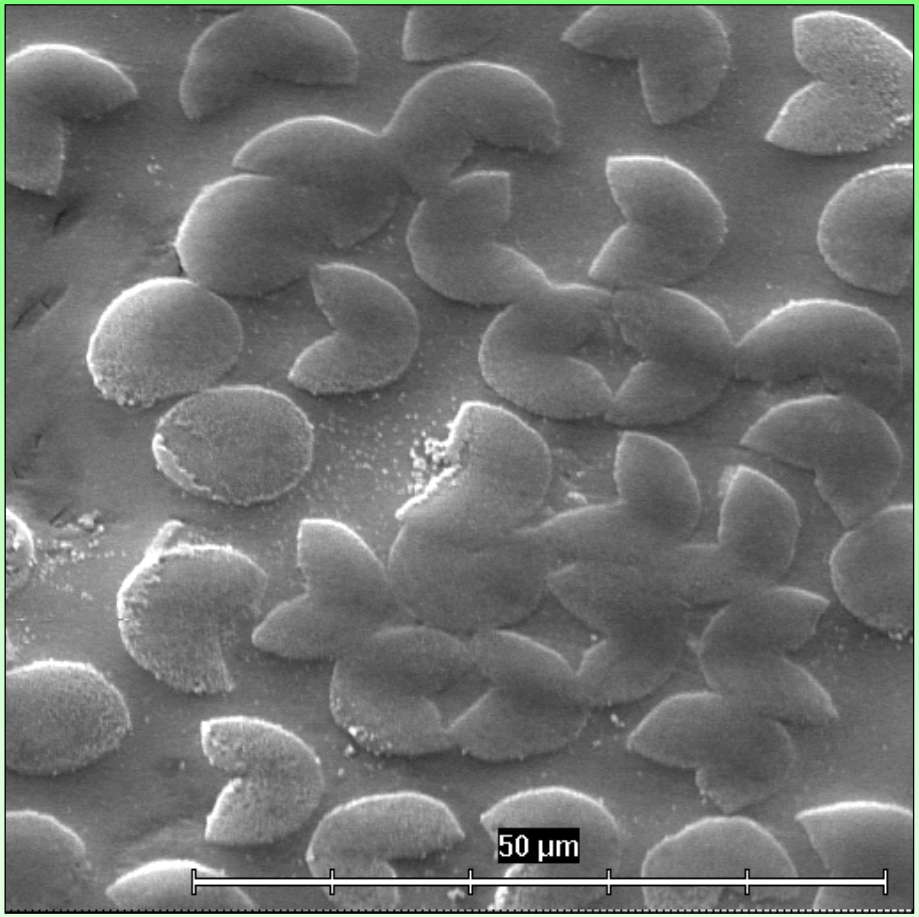

Intensity [counts]
5600
4800
4000
3200
2400
1600
800
0
0 1 2 3 4 5 6 7 8 9 10
Energy [keV]
C K
Cr L
Cr K
Cr K


20 µm

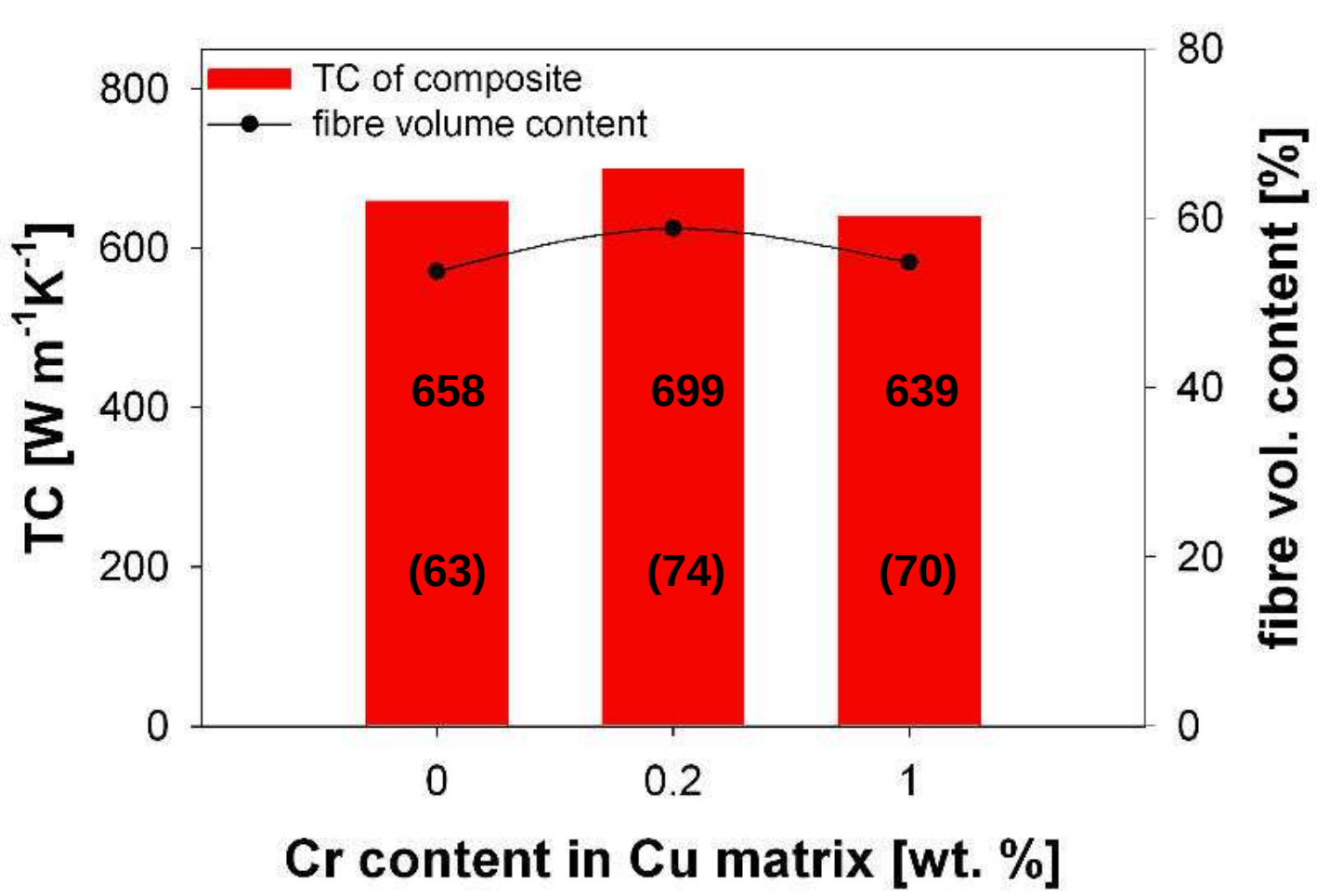

1µm

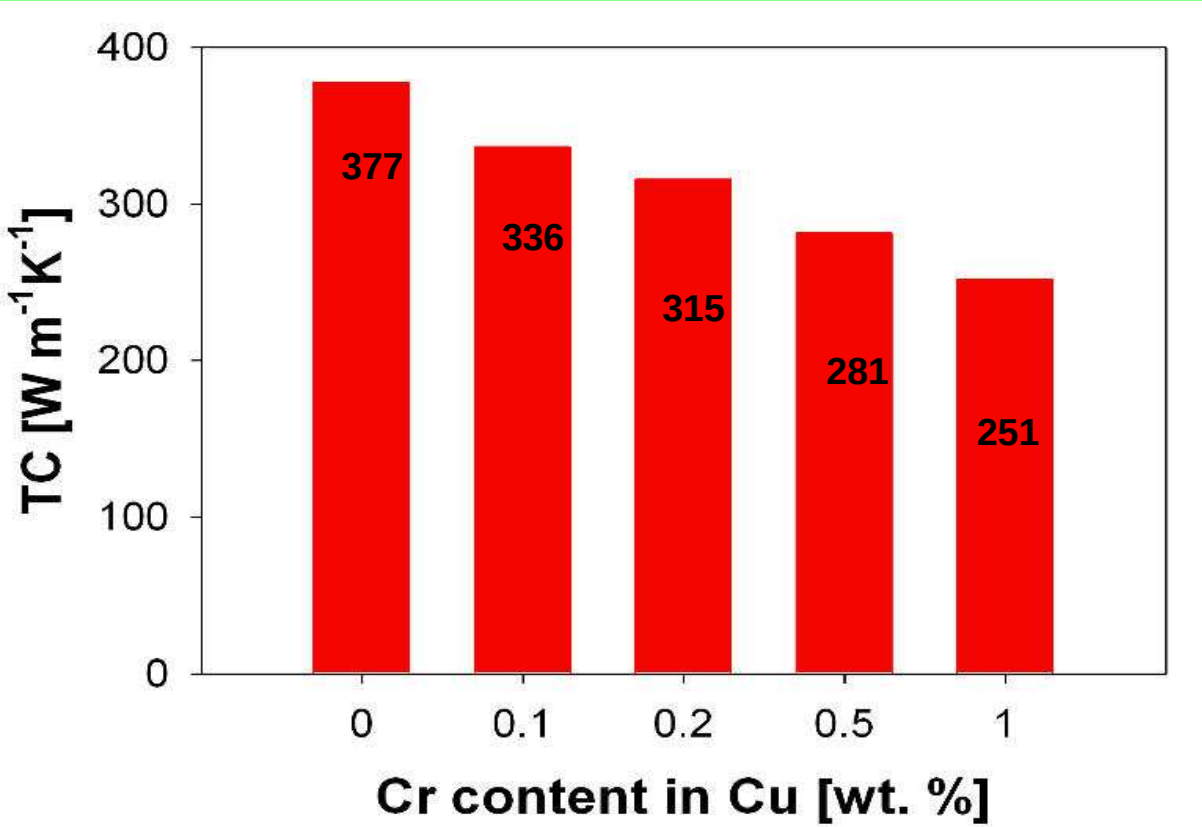


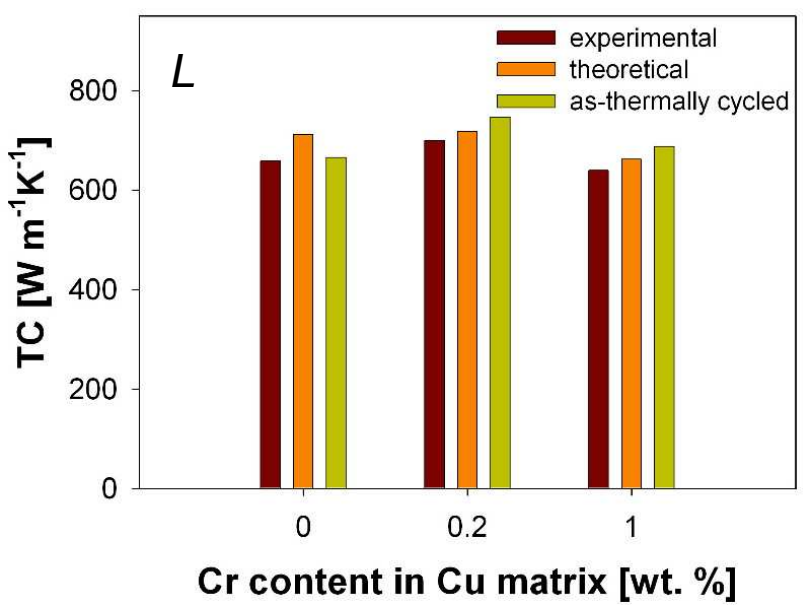
Structure of Al3Mg-K1100 composite a) without and b) with TiN separator particles

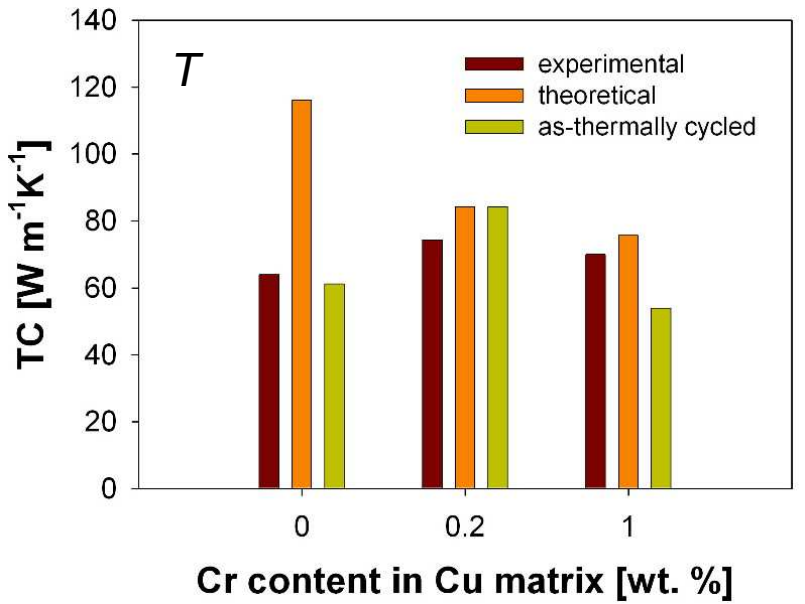


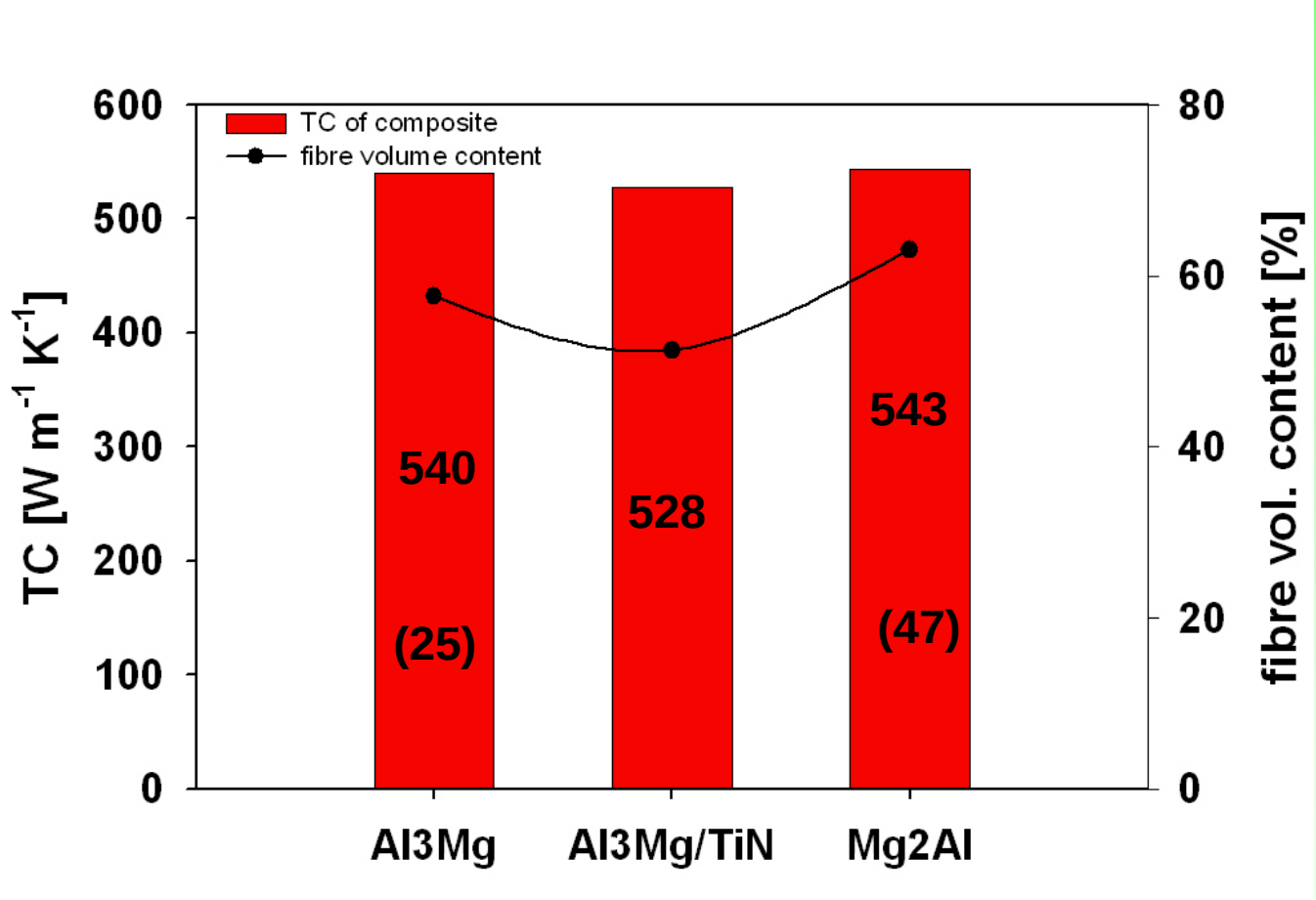
Structure of Mg2Al-K1100 composite

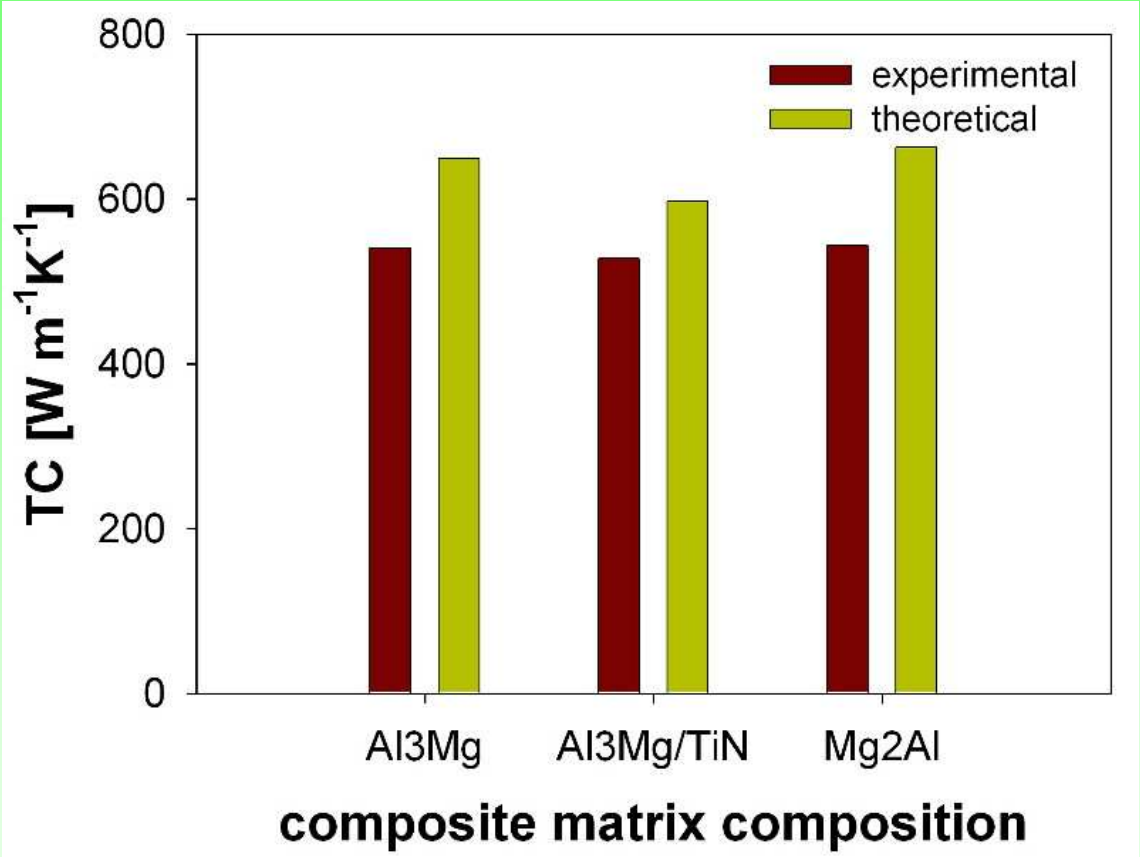

TC of composite
fibre volume content
800
600
400
200
0
80
60
40
20
0
658
699
639
(63)
(74)
(70)
0
0.2
1
TC [W m-1K-1]
fibre vol. content [%]
Cr content in Cu matrix [wt. %]


400
300
200
100
0
TC [W m-1K-1]
377
336
315
281
251
0
0.1
0.2
0.5
1
Cr content in Cu [wt. %]


L
experimental
theoretical
as-thermally cycled
TC [W m-1K-1]
800
600
400
200
0
0
0.2
1
Cr content in Cu matrix [wt. %]


T
experimental
theoretical
as-thermally cycled
TC [W m-1K-1]
140
120
100
80
60
40
20
0
0
0.2
1
Cr content in Cu matrix [wt. %]


TC of composite
fibre volume content
TC [W m-1 K-1]
fibre vol. content [%]
600
500
400
300
200
100
0
80
60
40
20
0
540
(25)
528
543
(47)
Al3Mg
Al3Mg/TiN
Mg2Al


800
600
400
200
0
TC [W m-1K-1]
experimental
theoretical
Al3Mg
Al3Mg/TiN
Mg2Al
composite matrix composition

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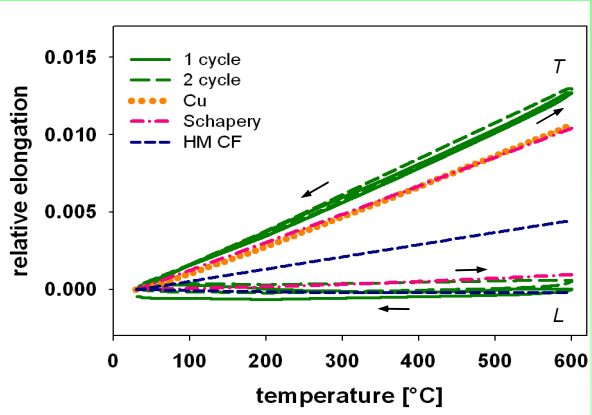
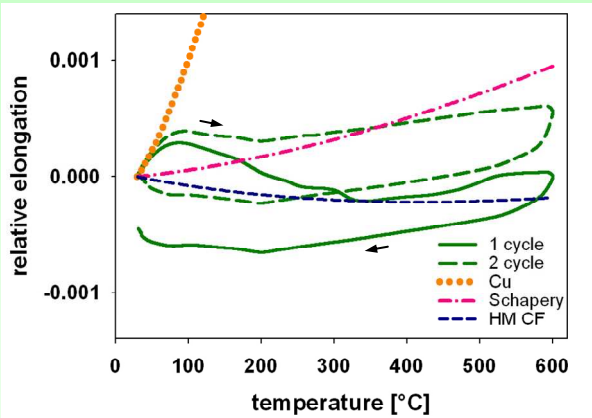
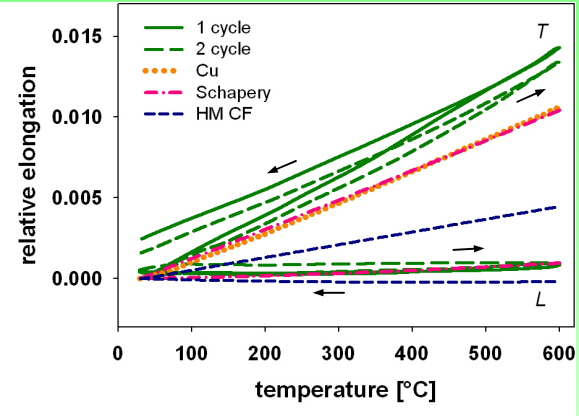
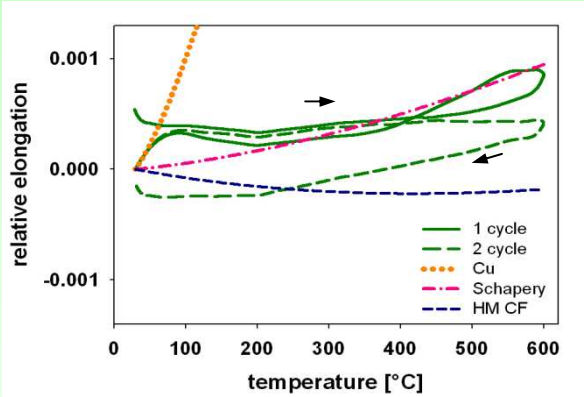
Cu-K1100



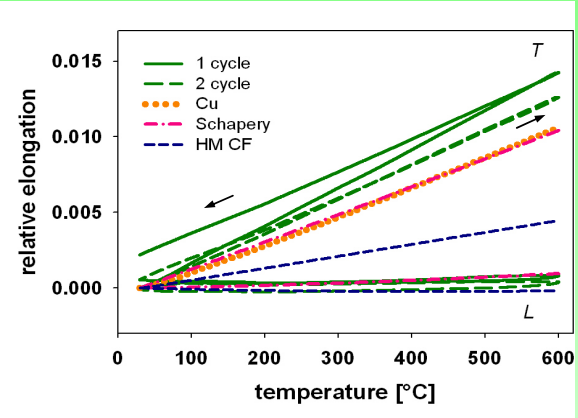


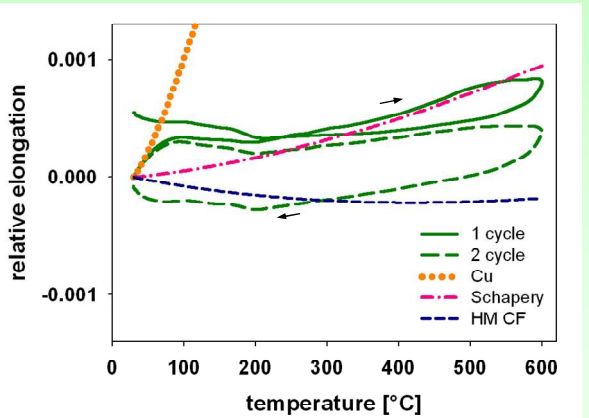
Cu0.2Cr-K1100





Cu1Cr-K1100





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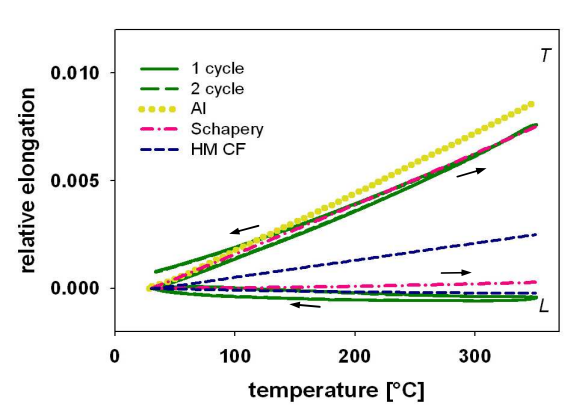
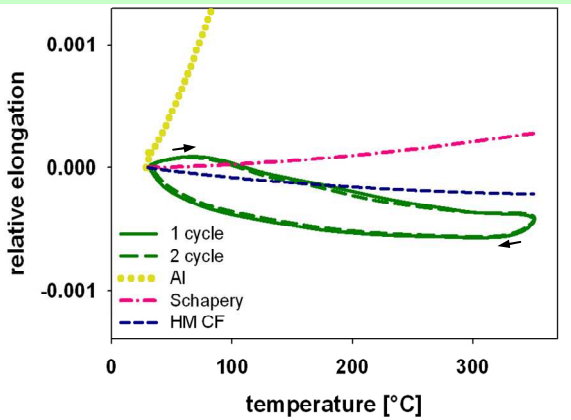
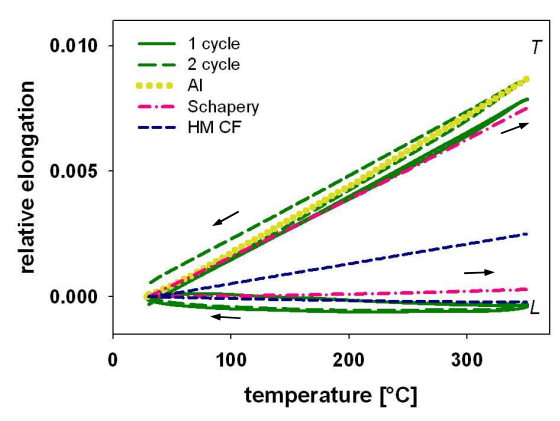
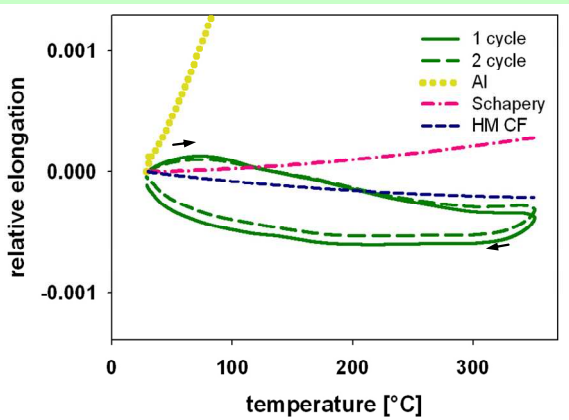
Al3Mg-K1100



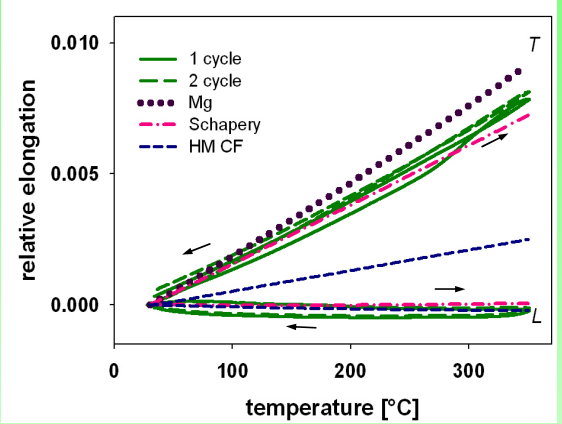


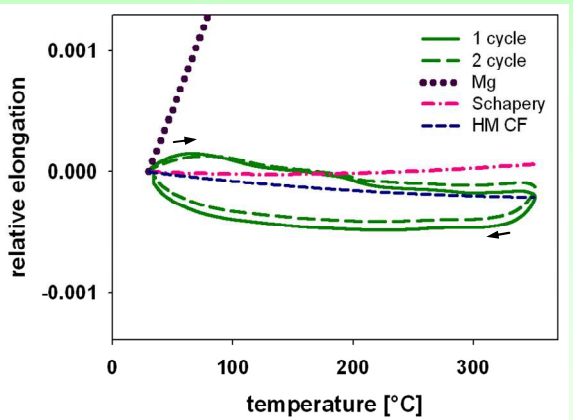
Al3Mg-K1100 s TiN





Mg2Al-K1100





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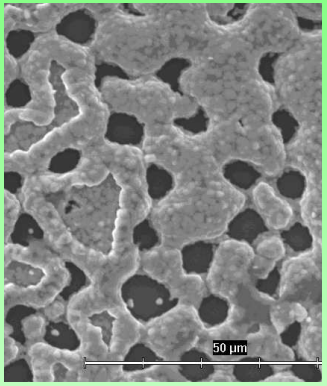
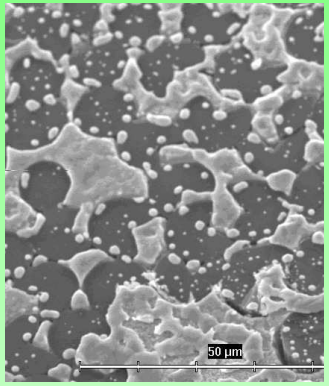
Cu-K1100



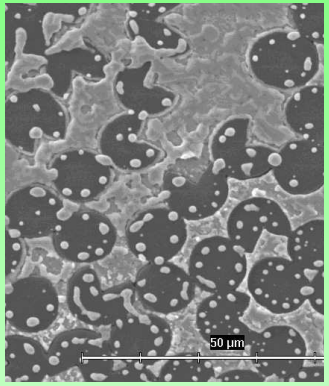
600℃

Cu0.2Cr-K1100



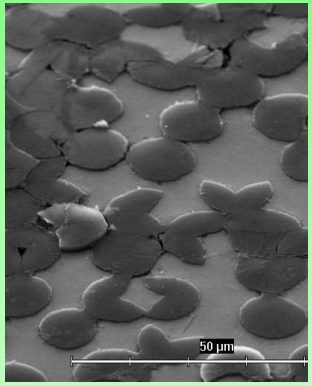
600℃

Cu1Cr-K1100



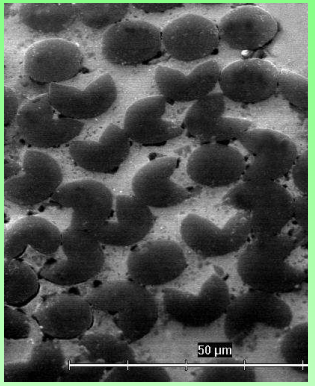
600℃

Al3Mg-K1100

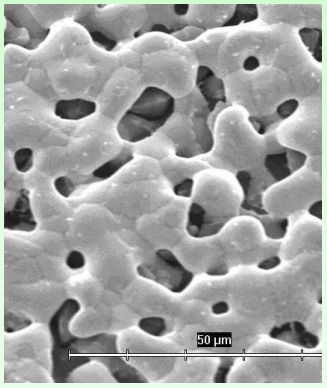


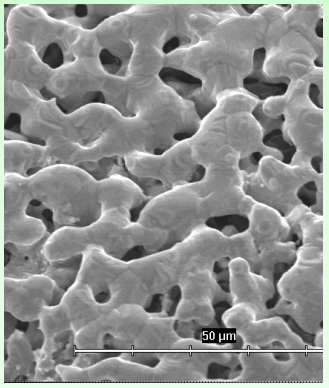
350℃

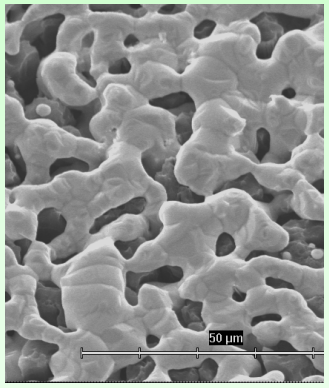
Mg2Al-K1100



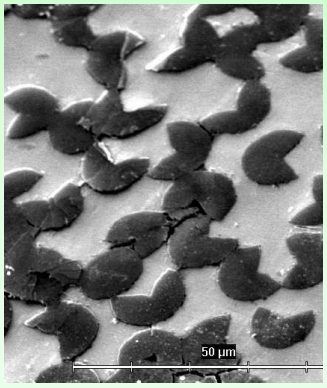
350℃







Al3Mg-K1100 s TiN



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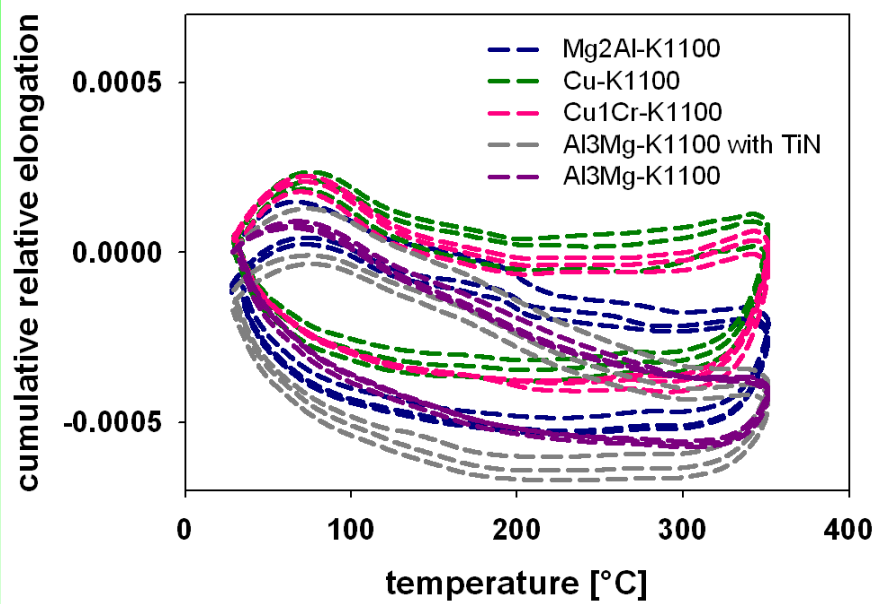

- negative CTE in the whole temperature range
- small differences in thermal expansion
- stronger interfaces in v Al3Mg-C and Mg2Al-C composites
- smaller residual stresses in Al3Mg-C and Mg2Al-C composites

CTE [$10^{-6}K^{-1}$]	Cu-K1100		Cu1Cr-K1100		Al3Mg-K1100		Al3Mg-K1100 s TiN		Mg2Al-K1100	
150-250℃	heat.	cool.	heat.	cool.	heat.	cool.	heat.	cool.	heat.	cool.
CTE_L	-0.7	-0.7	-0.9	-0.9	-1.9	-1.7	-1.8	-1.6	-1.1	-0.9
CTE_T	21.1	19.7	21.4	20.6	23.8	20.8	27.4	25.3	26.4	23.2

Conclusions

- the interfacial bonding in metal matrix (Cu, Al, Mg) can be effectively influenced by proper matrix alloying and kinetic parameters of infiltration
- higher TC and lower CTE in all composites has been achieved when compared with pure Cu
- composites can be used as heat sink materials particularly in those cases where materials with high thermal conductivity and low CTE are required and the anisotropy can be accepted (utilized)
- MgAl-K1100 and AlMg-K1100 can be used in applications where low density is required
- the role of interface in the composites reinforced with unidirectionally aligned continuous fibres appears to be not as dominant as in short fibre or particulate reinforced composites

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Thank you for your attention