THE EFFECT OF BONDING AND BAKEOUT THERMAL CYCLES ON THE PROPERTIES OF COPPER ALLOYS IRRADIATED AT 100°C - D.J. Edwards (Pacific Northwest National Laboratory)*, B.N. Singh, P. Toft and M. Eldrup (Risø National Laboratory)

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EXTENDED ABSTRACT

This report describes the final irradiation experiment in a series of screening experiments [1,2] aimed at investigating the effects of bonding and bakeout thermal cycles on irradiated copper alloys. Tensile specimens of CuCrZr and CuNiBe alloys were given various heat treatments corresponding to solution anneal, prime-ageing and bonding thermal treatment. [illegible]ged and given a reactor bakeout treatment at 350°C for 100 [illegible] heat treatment corresponding to a bonding thermal cycle [illegible] irradiated at 100°C to a dose level of ~0.3 dpa in the DR-3 [illegible] tests at 100°C, electrical resistivity, and microstructural examination were performed. Testing and analysis of the unirradiated specimens have been reported earlier [1,2].

The post-irradiation tests at 100°C revealed the greatest loss of ductility occurred in the CuCrZr alloys, irrespective of the pre-irradiation heat treatment, with the uniform elongation dropping to levels of less than 1.5%. The yield and ultimate strengths for all of the individual heat treated samples increased substantially after irradiation. The same trend was observed for the CuNiBe alloys, which overall exhibited a factor of 3 higher uniform elongation after irradiation with almost double the strength. In both alloys irradiation-induced precipitation lead to a large increase in the strength of the solution annealed specimens with a noticeable decrease in uniform elongation. The Al25 alloy also experienced an increase in the overall strength of the alloy after irradiation, accompanied by approximately a 50% decrease in the uniform and total elongation. The additional bakeout treatments given to the CuCrZr and CuNiBe before irradiation served to increase the strength, but in terms of the ductility no improvement or degradation resulted from the additional thermal exposure. The results of this experiment confirm that the Al25 possesses the most resistant microstructure to thermal and irradiation-induced changes, while the competing effects of ballistic dissolution and reprecipitation lead to important changes in the two precipitation strengthened alloys. This study and others have repeatedly shown that these materials can only be used if the very low uniform elongation (1% or less) can be accounted for in the design since pre-irradiation thermal processing cannot mitigate the irradiation embrittlement.

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Table 1. Tensile results for copper alloys irradiated at 100°C to 0.3 dpa. Tests were conducted at 100°C.

Material	Heat Treatment	$\sigma_{0.05}$ (MPa)	$\sigma_{0.2}$ (MPa)	σ_{max} (MPa)	ε^p_u (%)	ε_{total} (%)
CuNiBe	Solution annealed	625	663	683	12.5	14.5
CuNiBe	Bonding Cycle	800	880	938	3.4	5.9
CuNiBe	B + Bakeout	880	960	990	3.4	5.4
CuNiBe	Prime Aged	815	885	940	3.3	5.9
CuCrZr	Solution annealed	365	365	370	1.1	4.0
CuCrZr	Bonding Cycle	370	370	373	1.1	4.1
CuCrZr	B + Bakeout	445	450	450	1.3	4.0
CuCrZr	E + Bakeout	440	440	445	1.3	4.0
CuCrZr	Prime Aged	400	405	412	1.2	3.8
Al25*	Annealed	540	544	546	5.5	26.0

* Round specimen, 3 mm diameter gage

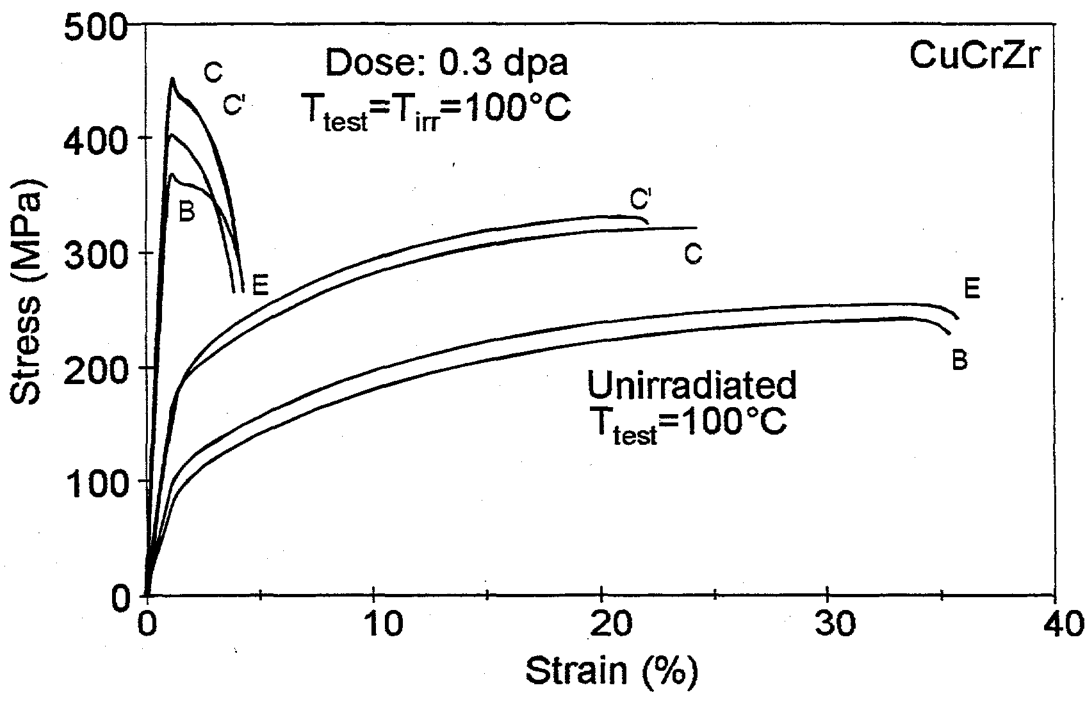

Figure 1. The tensile properties of the various heat treated CuCrZr specimens before and after irradiation. Irradiation leads to a severe loss of uniform and total elongation, and produces an instability upon yielding. The embrittlement is not affected by the pre-irradiation heat treatment.

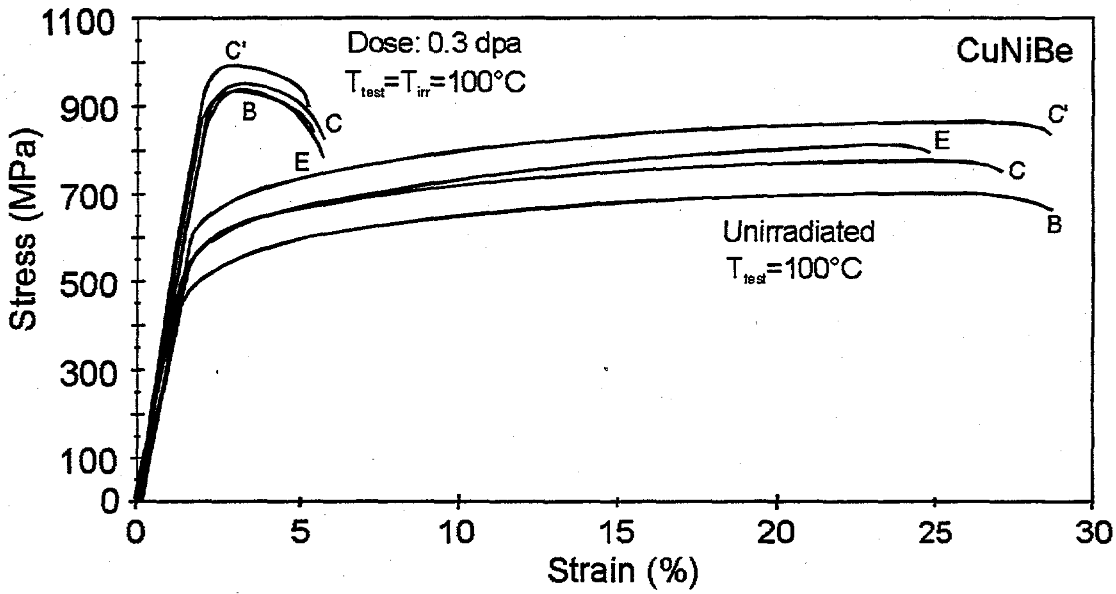

Figure 2. The tensile properties of the various heat treated CuNiBe specimens before and after irradiation. Irradiation produces a significant increase in strength and loss of ductility, but does not lead to the instability shown for the CuCrZr alloys.

REFERENCES

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