ASIPP

Flat Tungsten High Heat Flux Components Development Based on Different Technology

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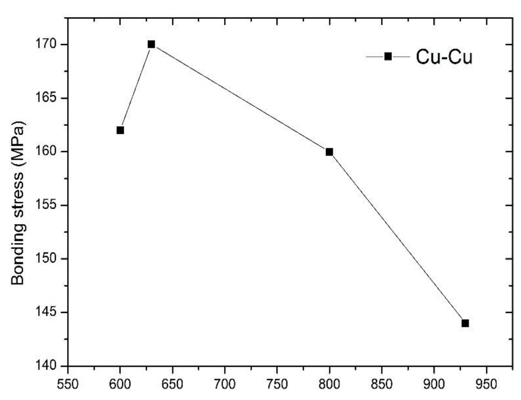
Introduction

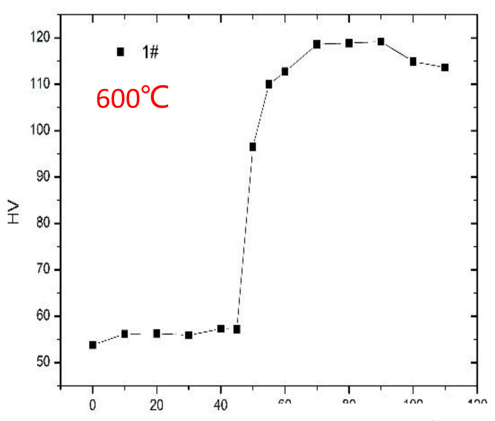
High heat flux components for fusion reactor divertor plasma facing targets are required could handle heat flux no less than 10MW/m^2 with no damage on plasma facing material and heat sink material. The ITER monoblock tungsten structure for divertor targets is a very good example for high heat flux. To get more efficient cooling and reduce manufacturing cost the flat type target with tungsten slices bonding to copper alloy plate is one of options. Here introduce tungsten bonding to CuCrZr heat sink with pure copper as interlayer with different technology. HIP, braze and nanoporous active technology were applied for materials bonding. Properties of bonding from different technology is shown as below.

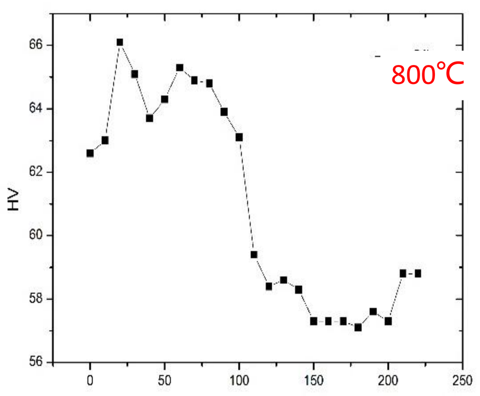
HIPing technology

Before tungsten bonding to CuCrZr pure copper was casted to tungsten. During casting oxygen should be controlled as low as possible. Temperature must let copper melting but cannot above tungsten recrystallization point. Interface UT result shows defects cannot be avoided if only cast Cu to tungsten. HIP technology apply to improve cast bonding. After HIP UT detectable defects between W and Cu cannot find. W/Cu slices HIP to CuCrZr heat sink under 600°C, 100MPa for 3 hours. UT shows there are only few detectable defects were found on a plate with more than 100 W/Cu slices. Mock-up high heat flux testing shows 10MW/m^2 heat flux can be handled for steady state.

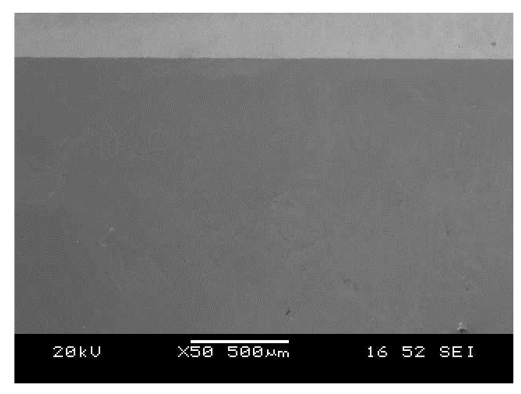


Tensile strength of Cu-CuCrZr bonding

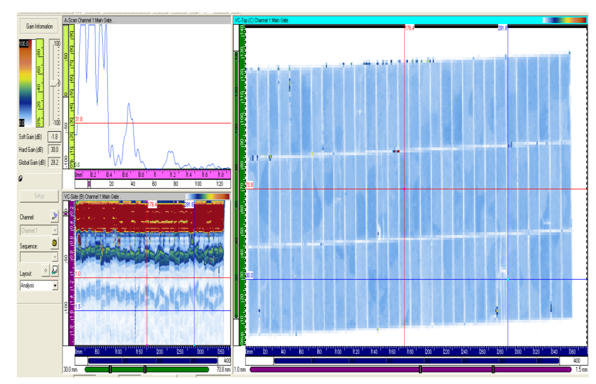




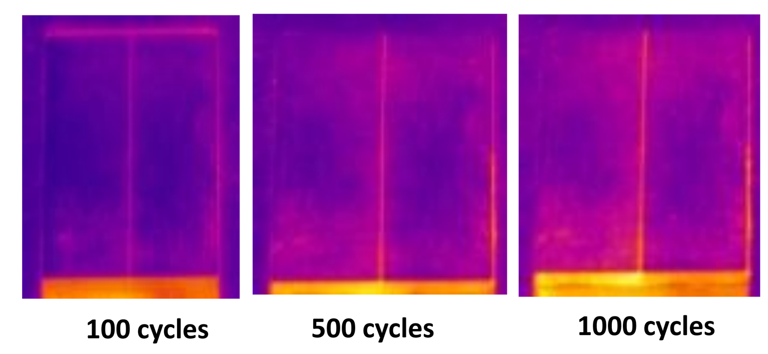
Micro hardness of Cu-CuCrZr interface



Cu-CuCrZr interface



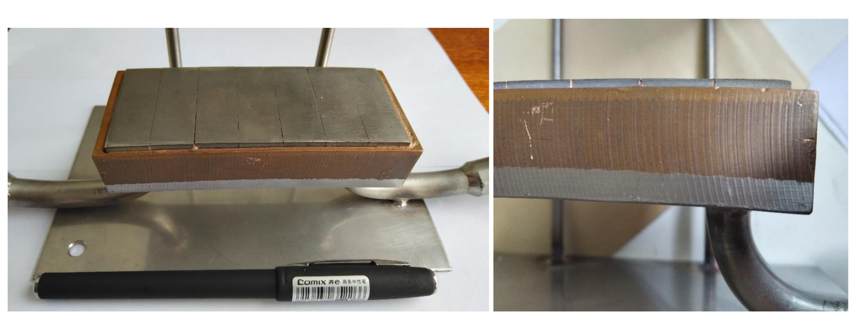
UT detect result of Cu-CuCrZr interface



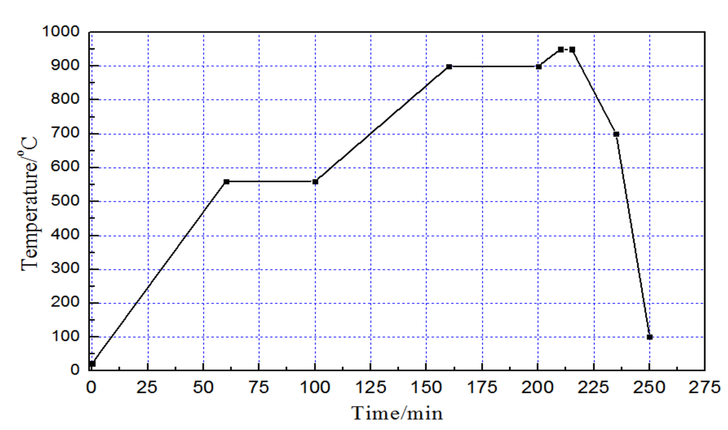
Mock-up 10MW/m^2 heat flux test

Brazing technology

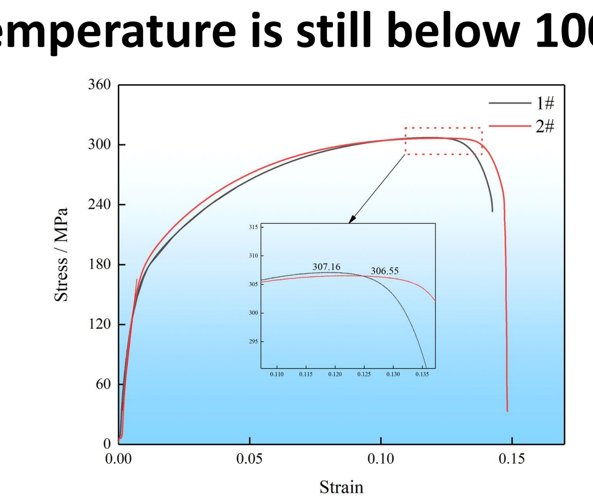
A new type of cooling channel structure was designed. It can improve cooling efficiency. Cooling channels machining both on CuCrZr plate and SS-316L plate with turbulence slices on CuCrZr plate. Then these channels was filled with special material and two plates explosion welded together. The special material was removed both by heating chemical reaction after bonding. Tungsten and pure copper was bonded still by casting + HIPing, and W/Cu slices brazing to CuCrZr. High heat flux testing showed: 15MW/m^2 heat flux test was apply on mock-up and tungsten surface temperature keep below 800°C, and 1000 cycles without any damage; 20MW/m^2 heat flux applied tungsten surface temperature is still below 1000°C.



W brazing Mock up



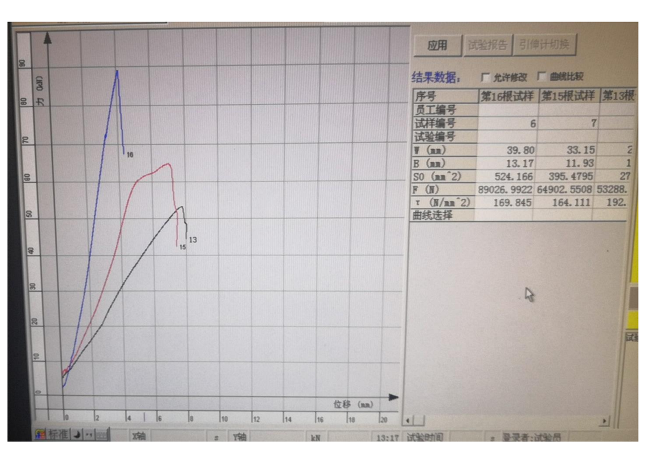
Temperature process of Brazing



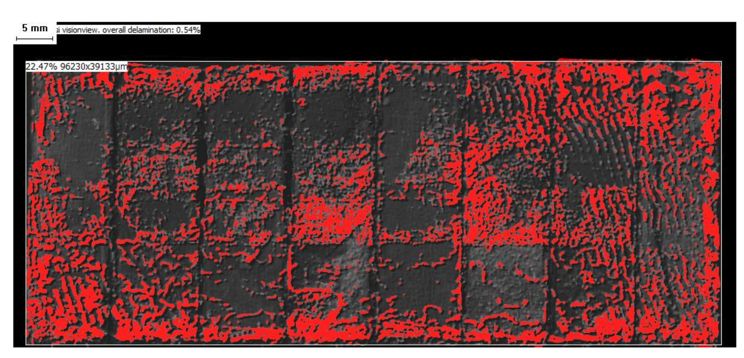
CuCrZr tensile strength after brazing

component	Cu	Mn	Ni	Cr	Si	Fe	Ti
percentage	rest	26	10	1	0.5	0.5	1.5

Filer metal composition



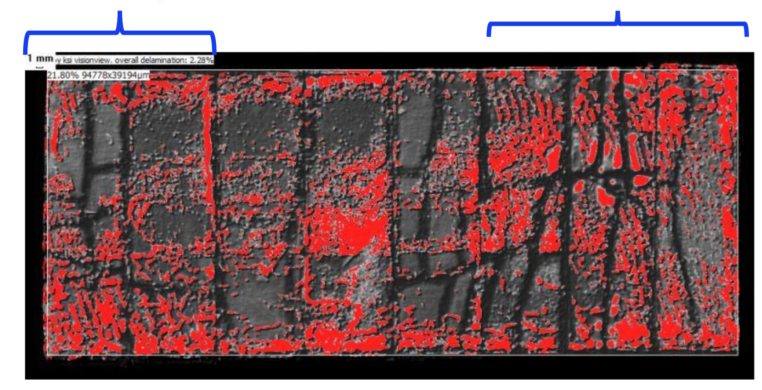
CuCrZr share strength after brazing



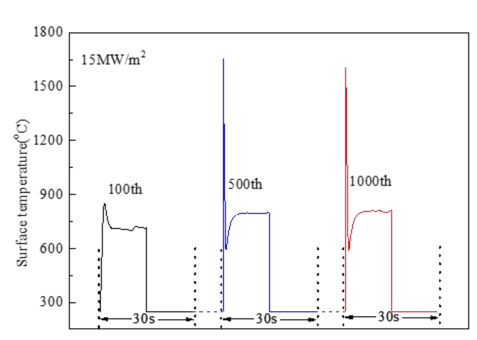
Before HHF testing

20MW/m^2
100 cycles

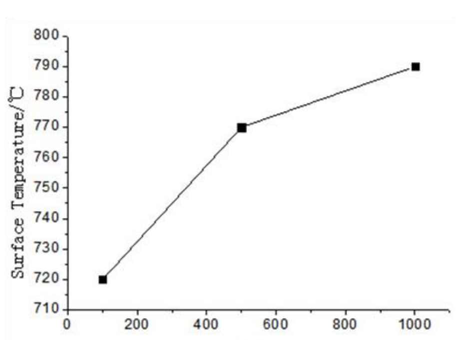
15MW/m^2
1000 cycles



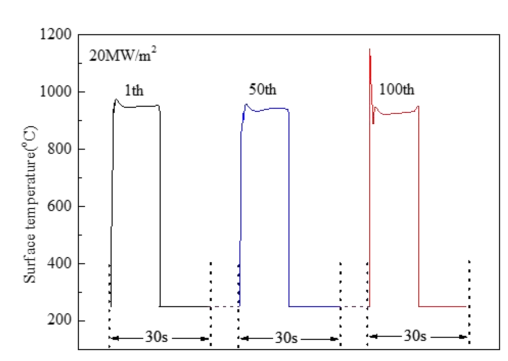
After HHF testing

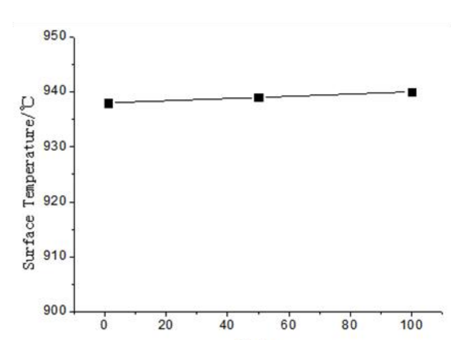


1000cycles with heat flux 15MW/m^2



W surface status after 15MW/m^2 1000 cycles test



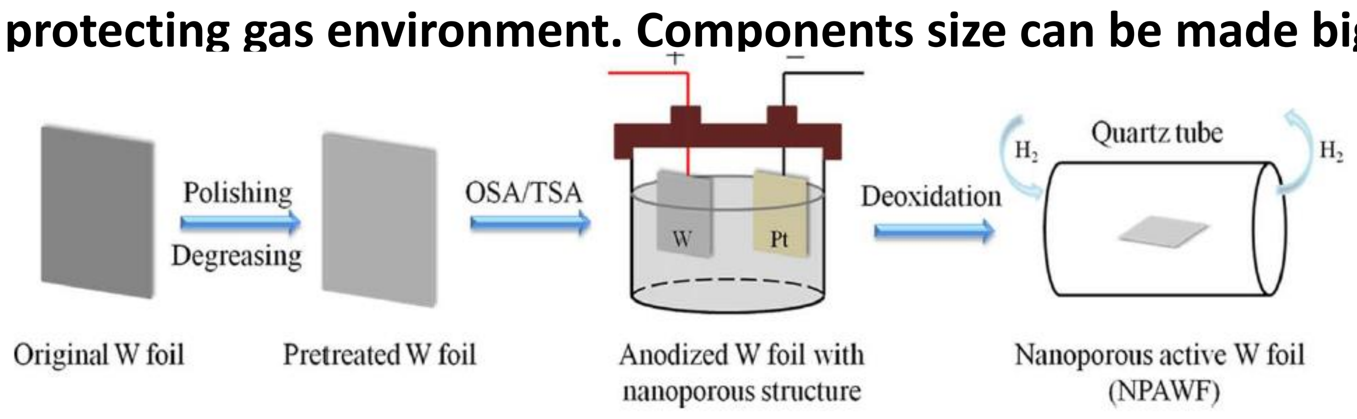


100cycles with heat flux 20MW/m^2

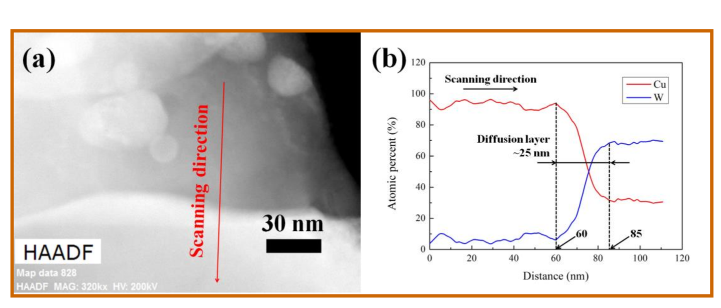
W surface status after 20MW/m^2 100 cycles test

Nanoporous active technology

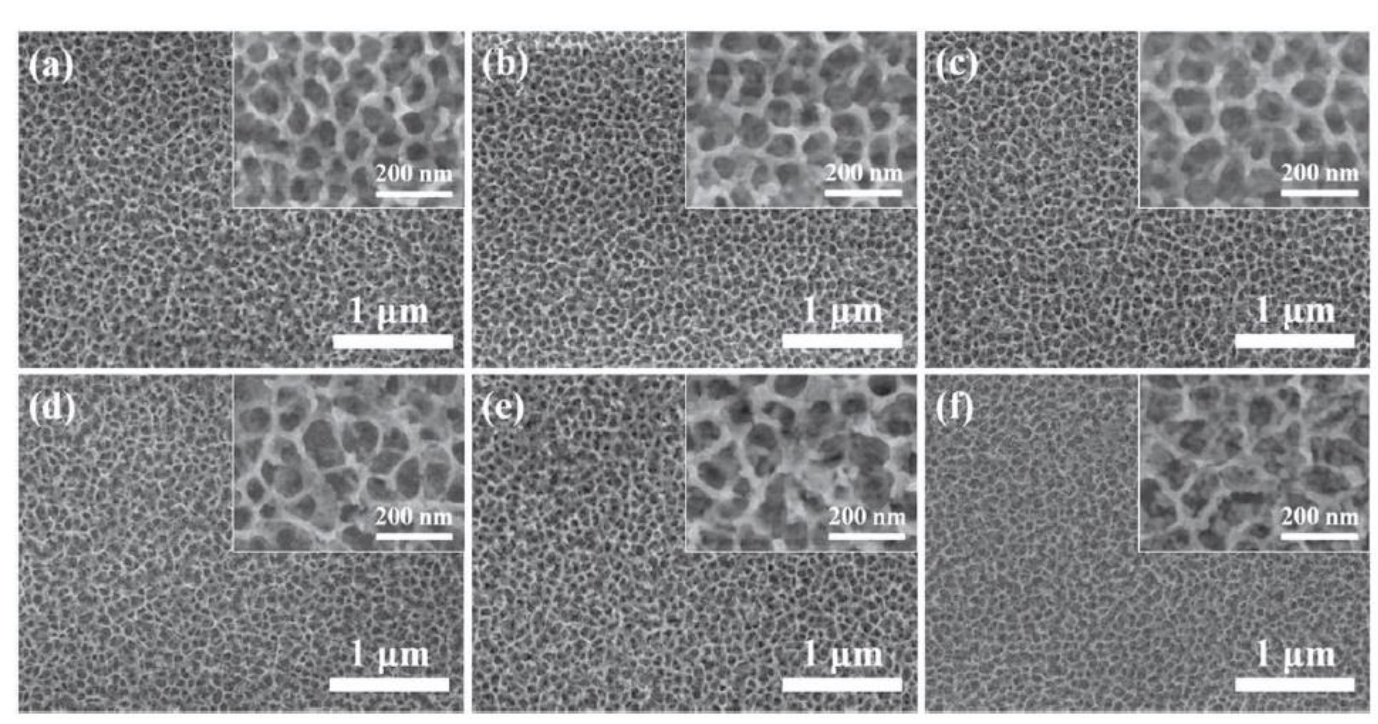
Electrochemical method was applied to make nanoporous structure on tungsten slices surface. Ordered nanoporous structure with an average pore size of several tens nanometers on the surface. After that pure copper was electroplated to fill the nanoporous and cover the surface with thickness around 10µm. In this case copper can be bonded to tungsten slices and get high bonding strength. Before W/Cu slices is bonded to CuCrZr interface surface both on copper and CuCrZr was polished to roughness up to 1.6 µm. Then W/Cu slices can be bonded to CuCrZr under 450°C and 100MPa pressure. The CuCrZr material properties degradation can be avoided. This bonding was completed under pressure from mechanical jig and components heating in vacuum or protecting gas environment. Components size can be made bigger and manufacturing cost was decreased much compare with HIP.



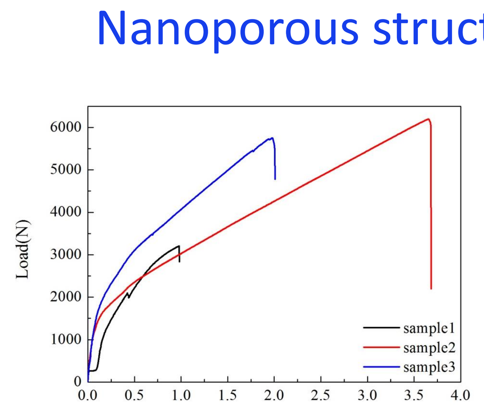
Nanoporous structure making process

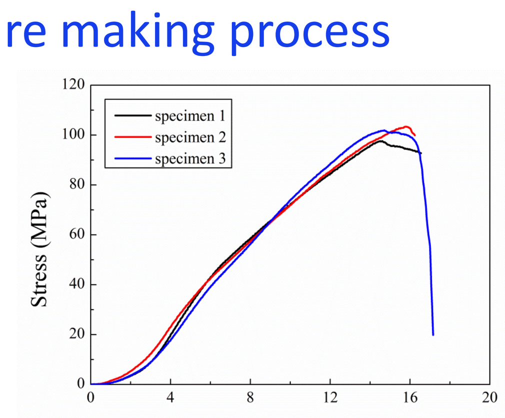


W/Cu interface

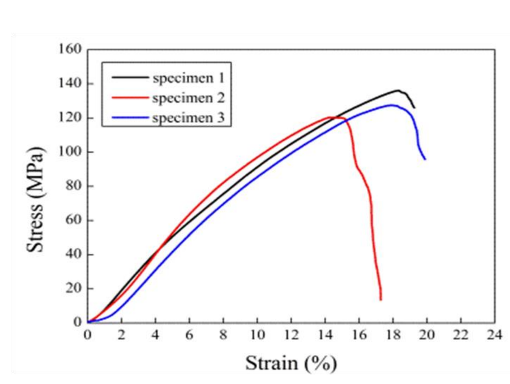


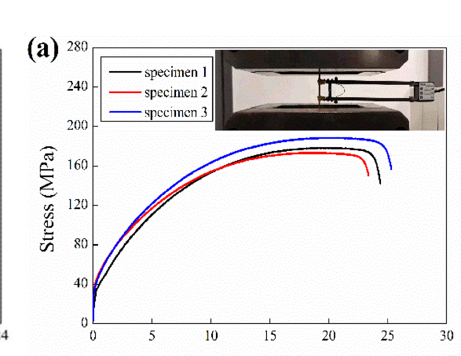
Nanoporous structure making by different condition





W/Cu interface tensile and share property





Cu/CuCrZr interface share and tensile property