# IMSTEC 2016

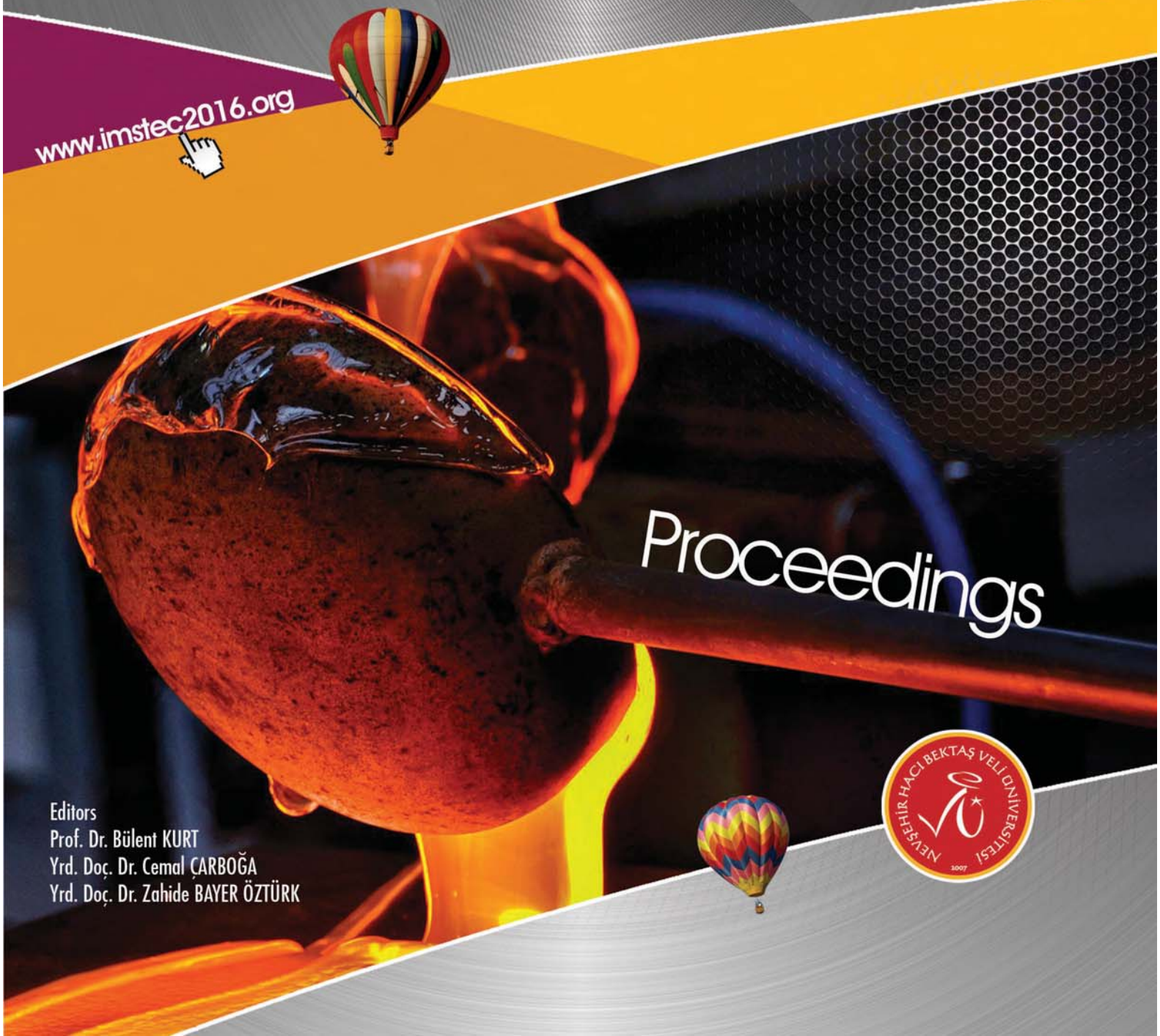
Nevşehir Hacı Bektaş Veli University

International Conference on

# Material Science and Technology in Cappadocia

6/8 April 2016

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## Proceedings


Editors
Prof. Dr. Bülent KURT
Yrd. Doç. Dr. Cemal ÇARBOĞA
Yrd. Doç. Dr. Zahide BAYER ÖZTÜRK




# BİLDİRİLER KİTABI

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# PROCEEDINGS

Publication of the communiques issued in this book is possible provided that written approval of the author and editor are taken. Given reference is sufficient for extraction.

Bu bildiri kitabı aşağıdaki adresten edinilebilir.

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Nevşehir Haci Bektas Veli University
Engineering-Architecture Faculty
Metalurgy and Material Engineering
2000 Evler Mah. Zübeyde Hanım Cad. 50300/Nevşehir/TÜRKİYE
Phone: +90 384 228 10 00 (15051)
Fax: +90 384 228 10 37
E-mail : imstec16@gmail.com

# PREFACE

International Conference on Material Science and Technology in Cappadocia (IMSTEC'16) organised by Nevsehir Haci Bektas Veli University and BAYEM Ajans is held in April 6-8, 2016 in Nevsehir, Turkey. This symposium is aimed at bringing together academics, researchers and engineers, iron and steel manufacturers, exporters and importers, suppliers, technology producers and non-governmental organizations around the world to share and discuss their latest works and the new methodologies to improve the structure and properties of the materials. The topics of IMSTEC'16 covered are Metallurgy and materials, Casting, Heat treatment, Coating and corrosion, Welding and cutting, Forming and machining, Energy and environment, Marketing and finance, Automation, Occupational health and safety.

The Symposium includes invited papers of national and international academicians and the papers submitted by academia in all aspects of the material industries.

Cappadocia region, the capital of Nevşehir, has one of the most interesting and spectacular landscapes in the World, which is the first settlements dating back to 3000 BC; The oldest name was "Nyssa". It is the perfect starting point to visit the area. The castle standing at the highest point in the city which comes from seljuks period is also one of the most intersting ruins. The Kursunlu Mosque has an impressive complex of buildings and a medresse surrounding it which dates back to 1726. The museum displays a rich collection of the local finds. Gulsehir, and Hacibektas which is the town where Haci Bektas Veli settled in the 14th century, and set up his own Bektas Dervish order which was based on love and humanism.

We would like to express our sincere thanks to those who spend great effort to make this event take place. We would also like to thank to BAYEM Ajans and other sponsors of IMSTEC'16 as their names and company logos stated. We also express our gratitude to the members of Honorary Committee, Scientific Committee, Organizing Committee, Secretarial Assistance, and Students for their great effort to make the event successful. Lastly, we would like to thank to academicians, practitioners, and the experts who were joined to ımstec'16 in order to share their knowledge.

With the wishes to see you all at the next International Symposium…

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Prof.Dr. Bülent KURT

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# IMSTEC'16 PROGRAM

| *6 APRİL 2016-6 NİSAN 2016* | |
|---|---|
| 09:00-10:30 | REGISTRATION/KAYIT |
| 10:30-11:15 | OPENING CEROMONY/AÇILIŞ TÖRENİ |
| 11:15-11:35 | **Nükleer Teknoloji:Bugünü ve Geleceği**<br>INVITED SPEAKER:Doç.Dr.Havva KAZDAL ZEYTİN |
| 11:35-11:55 | **Östenitik Alaşımların Nitrürlenmesi**<br>INVITED SPEAKER:Prof.Dr.Hüseyin ÇİMENOĞLU |
| 11:55-12:15 | **The Importance of Mechanical Signals in Tissue Engineering**<br>INVITED SPEAKER:Prof.Dr.Yannis F.Missirlis |
| 12:30-13:30 | **LUNCH/ÖĞLE YEMEĞİ** |
| ***Prof.Dr. Nuri ORHAN SESSION / Prof.Dr. Nuri ORHAN OTURUMU*** | |
| ***Session Chairman /Oturum Başkanı:****Prof. Dr. Bilge DEMİR* | ***HALL URGUP 1 / SALON ÜRGÜP 1*** |
| 13:30-13:50 | **ORBİTAL TIG VE MANUEL TIG KAYNAĞI İLE BİRLEŞTİRİLEN BORULARIN KAYNAK BÖLGESİ METALURJİK ÖZELLİKLERİNİN İNCELENMESİ**<br>Bekir Çevik, Alpay Özer |
| 13:50-14:10 | **SÜRTÜNME KARIŞTIRMA KAYNAĞI İLE BİRLEŞTİRİLMİŞ 7XXX SERİSİ Al ALAŞIMININ MİKRO YAPI VE MEKANİK ÖZELLİKLERİNİN ARAŞTIRILMASI**<br>Uğur AVCI, Mehmet ERDEM |
| 14:10-14:30 | **TOZ METALURJİSİ METODU İLE BRİKETLENEN AISI 1010 ÇELİĞİNİN İNDÜKSİYON FIRININDA SİNTERLENMESİNİN ARAŞTIRILMASI**<br>Vahdettin KOÇ |
| 14:30-14:50 | **P3HT/PCPDTBT/PCDTBT ESASLI ORGANİK GÜNEŞ PİLİ GELİŞTİRİLMESİ**<br>Yasin ALTIN, Süleyman GÜNGÖR, Ayşe BEDELOĞLU |
| ***Session Chairman /Oturum Başkanı:****Doç.Dr.Yavuz SUN* | ***HALL URGUP 2 / SALON ÜRGÜP 2*** |
| 13:30-13:50 | **BIOMIMETIC APPROACH FOR ICING PHENOMENON OF WIND TURBINES**<br>Kurtuluş Değer and Hüdayim Başak |
| 13:50-14:10 | **$Sm^{3+}$-ACTIVATED $Ho_2Sn_2O_7$ STRUCTURES AND PHOTOLUMINESCENCE PROPERTIES**<br>Esra ÖZTÜRK, Erkul KARACAOGLU |
| 14:10-14:30 | **SOLID-STATE SYNTHESIS OF LANTHANUM BORATES AT A REACTION TEMPERATURE OF 800°C**<br>S. Sari, A. S. Kipcak, F. T. Senberber, M. Yildirim and E. M. Derun |
| 14:30-14:50 | **POLYAMORPHIC PHASE TRANSITION IN ALUMINUM NITRIDE**<br>Murat Durandurdu |
| ***Session Chairman /Oturum Başkanı:****Prof.Dr.Cevdet GÖLOĞLU* | ***HALL ZELVE / SALON ZELVE*** |
| 13:30-13:50 | **GGG 40 VE 50 SERİSİ KÜRESEL GRAFİTLİ DÖKME DEMİR MALZEMELERDE MİKROYAPININ MEKANİK ÖZELLİKLERE ETKİSİ**<br>Mehmet GENÇER, Bülent BOSTAN, Sinan AKSÖZ, Hakan ADA |
| 13:50-14:10 | **KÜRESEL GRAFİTLİ DÖKME DEMİRLERDE ISIL İŞLEMİN MİKROYAPI VE MEKANİK ÖZELLİKLERE ETKİSİNİN İNCELENMESİ**<br>İlyas SOMUNKIRAN, Ahmet BALIN |
| 14:10-14:30 | **ŞEKİL BELLEKLİ NiTi ALAŞIMLARININ TOZ METALURJİSİ YÖNTEMİ İLE ÜRETİMİNDE SİNTERLEME SÜRESİNİN ETKİSİ**<br>Naci Arda TANIŞ, Bülent BOSTAN, Sinan AKSÖZ |
| 14:30-14:50 | **MODİFİYE GRAFEN OKSİT İÇEREN POLİMERİK KAPLAMANIN PERFORMANSININ İNCELENMESİ**<br>Mustafa ÇAKIR, Habibe İrem HELVACIOĞLU |
| ***Session Chairman /Oturum Başkanı:****Prof.Dr. Hayrettin AHLATCI* | ***HALL AVANOS / SALON AVANOS*** |
| 13:30-13:50 | **POST-WELD HEAT TREATMENT APPLIED in EXAMINING THE MECHANICAL PROPERTIES of 13CrMo4-5 and X10CrMoVNb9-1 GRADE STEEL**<br>Caner KIRBAS, Bunyamin CICEK, Murat BAYDOGAN and Huseyin CIMENOGLU |
| 13:50-14:10 | **EFFECT OF ADDITION OF $SIO_2$ NANOPARTICLES ON THE MECHANICAL PROPERTIES OF COLLAGEN HYDROLYSATE FILMS**<br>Buğra OCAK and **Ayşe ERCİYES** |
| 14:10-14:30 | **POLİMER NANOKOMPOZİTLER İÇİN BALL-ON-DİSK AŞINMA TEST CİHAZI TASARIMI VE PARAMETRE OPTİMİZASYONU**<br>Soner Savaş |
| 14:30-14:50 | **NANO-$AL_2O_3$ EFFECTS ON EPOXY ADHESİVES USED CARBON FIBER REINFORCED LAMINATED COMPOSITES**<br>Hasan ULUS, Halil Burak KAYBAL, Ahmet AVCI |

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| ***Session Chairman /Oturum Başkanı:****Prof.Dr Semra KURAMA* | ***HALL LODGE / SALON LODGE*** |
| 13:30-13:50 | **PRESSURELESS SİNTERİNG OF SiAlON CERAMİCS**<br>INVITED SPEAKER:Prof.Dr.Alpagut KARA |
| 13:50-14:10 | **ZN-AL-MG ALAŞIM KAPLAMANIN FARKLI KOROZİF ORTAMLARDAKİ AĞIRLIK KAYBININ GALVANİZ VE GALFAN KAPLAMA İLE KIYASLANMASI**<br>Teslime ORHAN, Erkan KARAYİĞİT |
| 14:10-14:30 | **KENDİ İLERYEN YÜKSEK SICAKLIK SENTEZLEMESİ İLE FERRİTİK PASLANMAZ ÇELİK ÜZERİNE $Ni_3Al$'NİN KAPLANMASI VE MİKROYAPI İNCELEMESİ**<br>Musa KILIÇ, Mustafa BEKEN, İhsan KIRIK, Niyazi ÖZDEMİR |
| 14:30-14:50 | **ÇİFT KATYON KATKILI YARI SAYDAM α-SİALON SERAMİKLERİN OPTİK ÖZELLİKLERİNİN ARAŞTIRILMASI**<br>Suna Avcıoğlu, Semra Kurama |
| ***Session Chairman /Oturum Başkanı:****Doç.Dr.Tacettin YILDIRIM* | ***HALL IHLARA / SALON IHLARA*** |
| 13:30-13:50 | **$C_NB_{6-n}H_6$ (n=0-6) TOPAKLARINDAKİ YAPISAL GEÇİŞ**<br>İskender Muz |
| 13:50-14:10 | **ELEKTRİK TÜKETİMİ VE KARBONDİOKSİT EMİSYONU ARASINDAKİ İLİŞKİNİN HİYERARŞİK YAPI YÖNTEMLERİ KULLANILARAK TOPOLOJİK ANALİZİ**<br>Şeyma Akkaya Deviren |
| 14:10-14:30 | **MECHANICAL PROPERTIES OF PRE-TREATED FUMED SILICA REINFORCED EPOXY NANOCOMPOSITE**<br>Mustafa Çakır,Emre Akın, Yüksel Akınay |
| 14:30-14:50 | **MAGNETIC PROPERTIES OF MIXED SPIN ISING NANOPARTICLES WITH $FE_4N$ STRUCTURE**<br>Bayram Deviren |
| 14:50-15:10 | ***COFFE BREAK / ÇAY-KAHVE ARASI*** |
| ***SESSION 2 / OTURUM 2*** | |
| ***Session Chairman /Oturum Başkanı:****Yrd. Doç. Dr. Yunus TÜREN* | ***HALL URGUP 1 / SALON ÜRGÜP 1*** |
| 15:10-15:30 | **GGG 40 VE 50 SERİSİ KÜRESEL GRAFİTLİ DÖKME DEMİR MALZEMELERDE MİKROYAPININ YÜZEY PÜRÜZLÜLÜĞÜNE ETKİLERİ**<br>Mehmet GENÇER, Bülent BOSTAN, Hakan ADA, Sinan AKSÖZ |
| 15:30-15:50 | **FARKLI BİR METOT KULLANARAK YENİ BİR TİP EĞRİSEL DİŞ PROFİLLİ DİŞLİ ÇARKLARIN ÜRETİMİ**<br>Mahir UZUN, Üsame Ali USCA, Yılmaz GÜR |
| 15:50-16:10 | **AISI 304 ÖSTENİTİK PASLANMAZ ÇELİĞİN TORNALANMASINDA BİTKİSEL ESASLI KATKI MADDELERİNİN YÜZEY PÜRÜZLÜLÜĞÜ ÜZERİNDEKİ ETKİLERİNİN DENEYSEL OLARAK ARAŞTIRILMASI**<br>Oğuz ÇOLAK, Emre HAMAMCI, Uğur UĞUREL, R. Can DOĞAN |
| 16:10-16:30 | **PLAZMA SPREY KAPLAMA TEKNOLOJİSİ VE UYGULAMALARI**<br>Yasin ÖZGÜRLÜK, Abdullah Cahit KARAOĞLANLI |
| 16:30-16:50 | **AISI 1040 ÇELİĞİNİN TORNALANMASINDA OLUŞAN MAKSİMUM PÜRÜZ DERİNLİĞİ İÇİN MATEMATİKSEL MODEL OLUŞTURULMASI**<br>Harun AKKUŞ, Harun YAKA, Levent UĞUR, Hayrettin DÜZCÜKOĞLU |
| 16:50-17:10 | **GRAFEN OKSİT İÇEREN POLİMERLERİN KAPLAMA PERFORMANSININ İNCELENMESİ**<br>Mustafa ÇAKIR, Yalçın BOZTOPRAK, İlyas KARTAL |
| ***Session Chairman /Oturum Başkanı:****Yrd.Doç.Dr.Mehmet ÜNAL* | ***HALL URGUP 2 / SALON ÜRGÜP 2*** |
| 15:10-15:30 | **QUANTITATIVE X–RAY DIFFRACTION ANALYSIS OF SPARK PLASMA SINTERED BORON CARBIDE–ALUMINUM COMPOSITES**<br>Irem Nur Gamze Simsek and Gursoy Arslan |
| 15:30-15:50 | **PRODUCTION OF POROUS SIC BASED CERAMICS VIA STARCH CONSOLIDATION TECHNIQUE**<br>Ayse KALEMTAS, Nigar OZEY |
| 15:50-16:10 | **IDENTIFING THE EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS USING TAGUCHI METHOD IN CNC HORIZONTAL FACE MILLING OF AUTOMOBILE PART SURFACES**<br>Ibrahim Sevim, Veysel Kara, S. Cinar Cagan, Mustafa Ugurlu |
| 16:10-16:30 | **SURFACE CHARACTERISATION OF BORIDED X210Cr12 STEEL**<br>Melih OZCATAL, Ibrahim GUNES |
| 16:30-16:50 | **THE EFFECTS OF THE REINFORCED TYPE ON THE WEAR BEHAVIOR OF AA6061 MATRIX COMPOSITES PRODUCED WITH HOT PRESSING METHODS**<br>İsmail Ovalı |
| 16:50-17:10 | **CUSHIONING PERFORMANCE of HOT WELDED POLYETHYLENE FOAMS**<br>Fatih Darıcık, Kerimcan Çelebi, Yılmaz Erbil, Serdar Güzel |

| *Session Chairman /Oturum Başkanı:Yrd.Doç.Dr.İlyas SOMUNKIRAN* | ***HALL ZELVE / SALON ZELVE*** |
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| 15:10-15:30 | **NANOKALSİT İÇEREN E-CAM/EPOKSİ TABAKALI KOMPOZİT PLAKANIN DÜŞÜK HIZ DARBE DAVRANIŞININ İNCELENMESİ**<br>Hasan Yavuz ÜNAL, Yeliz PEKBEY |
| 15:30-15:50 | **FARKLI SİNTERLEME SICAKLIKLARINDA ÜRETİLMİŞ Fe/$B_4C$-B KOMPOZİTLERİN METALOGRAFİK VE MEKANİK ÖZELLİKLERİNİN İNCELENMESİ**<br>Mustafa HAMAMCI, Fehmi NAİR, A. Alper CERİT |
| 15:50-16:10 | **ZİRKONYUMUN HOMOJEN AA6082 ALÜMİNYUM ALAŞIMININ ÖZELLİKLERİNE ETKİSİ**<br>Fulya Kahrıman, Muzaffer Zeren |
| 16:10-16:30 | **MELT SPINNING METODUYLA AA6060 ALUMİNYUM ALAŞIMI TOZ ÜRETİMİNİN İNCELENMESİ**<br>Sultan ÖZTÜRK, Sefa Emre SÜNBÜL, Kürşat İCİN, Bülent ÖZTÜRK Murat EROĞLU |
| 16:30-16:50 | **IN SITU ALÜMİNYUM MATRİSLİ KOMPOZİTLERİN FARKLI PARAMETRELERLE ÜRETİMİ**<br>Metin ÖNAL, Mehmet GAVGALI |
| 16:50-17:10 | **WCu KOMPOZİT MALZEMESİNİN MİKRO FREZELENMESİNDE İLERLEME VE KESME HIZININ TAKIM AŞINMASINA ETKİSİ**<br>Ali Erçetin, Muzaffer Erdoğan, Kubilay Aslantaş, Ömer Ekinci |
| *Session Chairman /Oturum Başkanı:Doç.Dr.M.Sabri GÖK* | ***HALL AVANOS / SALON AVANOS*** |
| 15:10-15:30 | **INCONEL 625 ALAŞIMININ BORLANMASI**<br>Hüseyin ÇAKIR, Erdoğan KANCA, Ali GÜNEN, Mehmet DEMİR, Faruk ÇAVDAR |
| 15:30-15:50 | **NEVŞEHİR İLİ TEHLİKELİ ATIK BEYANLARI VE TEHLİKELİ ATIK GERİ KAZANIM TESİSLERİNİN DEĞERLENDİRİLMESİ**<br>Seval ARAS, Feray YÜMÜN |
| 15:50-16:10 | **GÜÇLENDİRİLMİŞ AHŞAP KOMPOZİT LEVHALARIN YAPISI VE KULLANIMI**<br>Elif Yurttaş, Nadir Ayrılmış, Turgay Akbulut |
| 16:10-16:30 | **ŞEKİL HATIRLAMALI ALAŞIMLARDA MARTENSİTİK FAZ DÖNÜŞÜMÜ VE ŞEKİL HATIRLAMA MEKANİZMASI**<br>Mehmet Kaya, Kadri Can Atlı, Tuğba Yıldız Saygılı, Ömer Çakmak |
| 16:30-16:50 | **BİYOMALZEME VE KOROZYON**<br>Abdurrahman YOLUN, Mehmet KAYA, Abdurrahman AKKUŞ |
| 16:50-17:10 | **UZAYABİLEN, İLETKEN NANOLİF KOMPOZİTLERİN TERMAL, ELEKTRİKSEL VE MEKANİK ÖZELLİKLERİ**<br>Yasin ALTIN, Süleyman GÜNGÖR, Ayşe BEDELOĞLU |
| *Session Chairman /Oturum Başkanı:Prof.Dr. Serdar SALMAN* | ***HALL LODGE / SALON LODGE*** |
| 15:10-15:30 | **EFFECT OF AUSTENITIZATION TEMPERATURE ON TRIBOLOGICAL BEHAVIOUR OF MICRO-ALLOYED STEEL**<br>Mustafa Ulutan, Koray Kılıçay, Esad Kaya |
| 15:30-15:50 | **THERMAL PROCEDURE EFFECT ON Co-Al HIGH TEMPERATURE MAGNETIC SHAPE MEMORY ALLOY**<br>Fethi Dagdelen, Soner Buytoz, Mediha Kok, Türkan Malkoç |
| 15:50-16:10 | **DESIGN, SYNTHESIS, AND CHARACTERIZATION OF THREE NEW A,Ω - DISUBSTITUTED MOLECULES BASED ON INDENO[1,2-B]FLUORENE-6,12-DIONE AND THIOPHENE BUILDING BLOCKS.IMPROVEMENT OF AMBIPOLAR CHARGE CARRIER MOBILITIESVIA TAILORING OF ALKYL SUBSTITUENTS**<br>Mehmet Ozdemir , Resul Ozdemir, Choongik Kim, Hakan USTA |
| 16:10-16:30 | **THE EFFECT OF PYROLYSIS PARAMETERS ON THE YIELD AND SULPHUR CONTENT OF WASTE TIRE PRODUCTS**<br>Tuba Bahtlı (Aksoy), Derya Yeşim Hopa, Şerife Yalçın Yastı, , Veysel Murat Bostancı |
| 16:30-16:50 | **SİNTERLEME SICAKLIKLARININ TİCARİ SAFLIKTAKİ BİR SENTETİK HİDROKSİAPATİTE ETKİSİ**<br>Süleyman Serdar PAZARLIOĞLU, Serdar SALMAN |
| 16:50-17:10 | **DETERMINATION OF EFFECTIVE ATOMIC NUMBERS, EFFECTIVE ELECTRONS NUMBERS AND MASS ATTENUATİON COEFFİCİENTS FOR SOME STAINLESS STEELS IN THE ENERGY REGION 10 KEV – 100 GEV**<br>Aytaç Levet |
| *Session Chairman /Oturum Başkanı:Yrd. Doç. Dr. Volkan KIRMACI* | ***HALL IHLARA / SALON IHLARA*** |
| 15:10-15:30 | **FARKLI ORANLARDA SiC PARTİKÜL TAKVİYESİ YAPILMIŞ Cu MATRİSLİ KOMPOZİTLERİN MİKROYAPI VE MEKANİK ÖZELLİKLERİ**<br>Özgür Özgün, Zülküf Balalan, Ömer Ekinci |
| 15:30-15:50 | **TERMAL BARİYER KAPLAMALARIN (TBC) HASAR MEKANİZMALARININ İNCELENMESİ: KİMYASAL HASAR VE CMAS ETKİSİ SONUCU OLUŞAN HASARLAR**<br>Abdullah Cahit KARAOĞLANLI |

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| 15:50-16:10 | **MECHANICAL PROPERTIES OF SILANE TERMINATED URETHANE / EPOXY INTERPENETRATING NETWORK**<br>Mustafa ÇAKIR, Emre AKIN |
| 16:10-16:30 | **GRAFEN OKSİT İÇEREN POLİMERLERİN AŞINMA YÜZEY MORFOLOJİSİNİN İNCELENMESİ**<br>İlyas Kartal, Mustafa Çakır, Yalçın Boztoprak |
| 16:30-16:50 | **AŞINMA ODAKLI UYGULAMALARDA YÜKSEK HIZLI OKSİ-YAKIT (HVOF) SPREY KAPLAMA PROSESİNİN KULLANIMI**<br>Kadir Mert Döleker, Abdullah Cahit Karaoğlanlı |
| 16:50-17:10 | **THE EFFECTS OF $Li_2O$ IN THE $MgO$-$Al_2O_3$-$SiO_2$ GLASS-CERAMICS SYSTEM PRODUCED FROM MAGNESITE WASTE**<br>Cansu Utkan, Nuray Canikoğlu |
| ***SESSION 3 / OTURUM 3*** | |
| ***Session Chairman /Oturum Başkanı:*** *Doç. Dr. Tacettin YILDIRIM* | ***HALL URGUP 1 / SALON ÜRGÜP 1*** |
| 17:30-17:50 | **ABNORMAL GRAIN GROWTH IN DIFFUSION BONDING OF STEELS**<br>Bülent KURT |
| 17:50-18:10 | **PLASTİK GERİ DÖNÜŞÜM TESİSİ ATIKSULARININ KİMYASAL ARITIMI**<br>Serkan Şahinkaya |
| 18:10-18:30 | **MİG MAG TEKNİĞİ İLE BİRLEŞTİRİLEN BOR KATKILI 205 MANGANLI ÇELİĞİN MİKROYAPI ÖZELLİKLERİNİN ARAŞTIRILMASI**<br>C. ÇARBOĞA, B. KURT, S. DAL, B. DEMİR |
| 18:30-18:50 | **THE EFFECT OF MICRO ALLOY BORON ADDED ON MICROSTRUCTURE OF 304 STAINLESS STEEL**<br>C. Çarboğa, B. Kurt, S. Dal |
| ***Session Chairman /Oturum Başkanı:*** *Yrd.Doç. Dr. Erkan KALIPÇI* | ***HALL URGUP 2 / SALON ÜRGÜP 2*** |
| 17:30-17:50 | **FARKLI ORANLARDA AL İÇEREN TRIP ÇELİĞİNİN MİG-MAG KAYNAK TEKNİĞİ İLE KAYNAĞI VE MİKROYAPISININ İNCELENMESİ**<br>Cemal ÇARBOĞA, Bülent KURT, Serkan DAL |
| 17:50-18:10 | **METAL KAPLAMA ENDÜSTRİSİNDE ÇEVRESEL BİR ARAÇ OLARAK ATIK AZALTMA**<br>Hüseyin CÜCE, Muhammed BEYAZ |
| 18:10-18:30 | **EMAYE KAPLAMA ATIKSULARININ FENTON PROSESİ İLE ARITIMI**<br>Serkan Şahinkaya |
| ***Session Chairman /Oturum Başkanı:*** *Yrd.Doç.Dr.Zahide BAYER ÖZTÜRK* | ***HALL ZELVE / SALON ZELVE*** |
| 17:30-17:50 | **FARKLI ORANLARDA Sİ İÇEREN TRIP ÇELİĞİNİN MİG-MAG KAYNAK TEKNİĞİ İLE KAYNAĞI VE MİKROYAPISININ İNCELENMESİ**<br>Cemal ÇARBOĞA, Bülent KURT, Serkan DAL |
| 17:50-18:10 | **ALÜMİNYUMUN VE ÇELİK MALZEMEDEN ÜRETİLMİŞ NOZUL KULLANILAN KARŞIT AKIŞLI RANQUE-HİLSCH VORTEKS TÜPÜNDE ENERJİ-EKSERJİ ANALİZLERİNİN DENEYSEL OLARAK İNCELENMESİ**<br>Volkan KIRMACI |
| 18:10-18:30 | **A NOVEL APPLICATION OF EXPANDED POLYSTYRENE (EPS) FOAM AS ROOF COVERING MATERIAL**<br>B.Demirel and N.Atay |
| 18:30-18:50 | **THE COMPACT PRESSURE EFFECT OF POROUS NITI COATING ON COCRMO PM ALLOY SURFACE BY SHS PROCESS**<br>Bulent Kurt, Ilyas Somunkiran, Soner Buytoz, Khangardas ASGAROV |
| 19:00-22:00 | ***GALA DINNER / GALA YEMEĞİ*** |
| ***7 APRİL 2016 - 7 NİSAN 2016*** | |
| ***SESSION 4 / OTURUM 4*** | |
| ***Session Chairman /Oturum Başkanı:****Doç.Dr.Mehmet KAYA* | ***HALL URGUP 1 / SALON ÜRGÜP 1*** |
| 09:10-09:30 | **SİNTERLEME PARAMETRELERİNİN YİTRİYA STABİLE ZİRKONYA SERAMİKLERİNİN MEKANİK ÖZELLİKLERİNE ETKİSİ**<br>Emre Yalamaç, Elif Sıla Ergani, Mücahit Sütçü |
| 09:30-09:50 | **UÇUCU KÜL VE YUMURTA KABUĞUNDAN CAS ($CaO$- $Al_2O_3$- $SiO_2$) SERAMİKLERİN ÜRETİMİ**<br>Zafer Yavuz MERKİT, Nil TOPLAN |
| 09:50-10:10 | **Al-Cd FERRİTLERİN İLETKENLİK MEKANİZMASININ İNCELENMESİ**<br>T. Şaşmaz Kuru, E. Şentürk |
| 10:10-10:30 | **AISI 8620 ÇELİĞİ KULLANILARAK İLK DEFA İMAL EDİLEN EĞRİSEL EVOLVENT PROFİLLİ DİŞLİ ÇARKLARDA PİTTİNG OLUŞUMUNUN ARAŞTIRILMASI**<br>Mahir UZUN, Mehmet Mehdi MUNİS, Hayrettin DÜZCÜKOĞLU |

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| 10:30-10:50 | **VOLLASTONİT İLAVESİNİN HİDROKSİAPATİT-MgO KOMPOZİTİNDE POROZİTE DAĞILIMINA ETKİSİNİN İNCELENMESİ**<br>Şenol Avcı, Recep Artır |
| ***Session Chairman /Oturum Başkanı:****Doç.Dr.Murat ESKİL* | ***HALL URGUP 2 / SALON ÜRGÜP 2*** |
| 09:10-09:30 | **POLYAMİD, ALÜMİNYUMUN VE ÇELİK MALZEMEDEN ÜRETİLMİŞ NOZUL KULLANILAN KARŞIT AKIŞLI RANQUE-HİLSCH VORTEKS TÜPÜN PERFORMANSININ DENEYSEL OLARAK İNCELENMESİ**<br>Volkan KIRMACI |
| 09:30-09:50 | **ÇOK SAYIDA DELAMİNASYON HASARLI ÖRGÜ TAKVİYELİ E-CAM LİFİ/EPOKSİ KOMPOZİT MALZEMELERİN BASMA ve BURKULMA DAVRANIŞLARI**<br>Fatih Darıcık, Züleyha Aslan |
| 09:50-10:10 | **BASINÇLI INFILTRASYON YÖNTEMI ILE ÜRETILMIŞ IKILI MODEL SIC/AL2014 KOMPOZITIN MEKANIK FIZIKSEL ÖZELLIKLERINE INFILTRASYON SICAKLIĞI, BASINCI VE MG ILAVESININ ETKISI**<br>Serkan ATEŞ |
| 10:10-10:30 | **GLİSERİN VE PEG KATKILARININ İNCE ALÜMİNA TOZU TAKVİYELİ NA-METAKAOLİN ESASLI JEOPOLİMER BASMA DAYANIMI VE TERMAL DAVRANIŞINA ETKİSİ**<br>Süleyman YAŞIN, Hayrettin AHLATCI, Yunus TUREN, Engin CEVIK, Yavuz SUN, Harun ÇUĞ |
| 10:30-10:50 | **CR-39 PLASTİK POLİMER ÜZERİNE TEORİK BİR ÇALIŞMA**<br>Tuba ÖZDEMİR |
| ***Session Chairman /Oturum Başkanı:****Yrd. Doç. Dr.Nermin Demirkol* | ***HALL ZELVE / SALON ZELVE*** |
| 09:10-09:30 | **BOR İLAVESİNİN D2 TAKIM ÇELİĞİNİN MİKROYAPI VE MEKANİK ÖZELLİKLERİNE ETKİSİ**<br>Özgür Özgün, Mahir Uzun, Zülküf Balalan, H. Özkan Gülsoy, Ali Erçetin |
| 09:30-09:50 | **TOZ ENJEKSİYON KALIPLAMA YÖNTEMİ İLE PASLANMAZ ÇELİK (316L) MALZEMENİN ÜRETİMİ VE KARAKTERİZASYONU**<br>Mehmet ASLAN, Yunus TÜREN, Hayrettin AHLATCI, Yavuz SUN, Süleyman YAŞIN, Engin CEVIK, Mehmet ÜNAL |
| 09:50-10:10 | **AISI 1040 ÇELİĞİNDEN İMAL EDİLMİŞ MİLLERİN TORNALANMASINDA CVD Kaplamalı KESİCİ TAKIM AŞINMASININ İNCELENMESİ**<br>Ali ERÇETİN, Üsame Ali USCA |
| 10:10-10:30 | **1.2379 SOĞUK TAKIM ÇELİĞİNİN BORLANMASI**<br>Seyit Erkan AYDIN, Ahmet YAPICI,Erdoğan KANCA, Ali GÜNEN, Bülent KURT |
| 10:30-10:50 | **BOR NİTRÜR NANO LEVHALARIN EPOKSİ REÇİNENİN AŞINMA VE TERMAL KARARLILIĞI ÜZERİNE ETKİSİ**<br>Mürsel Ekrem, Muhammet A.Şenyurt, Hayrettin Düzcükoğlu, Ömer S Şahin, Ahmet Avcı |
| ***Session Chairman /Oturum Başkanı:****Yrd.Doç.Dr.Vahdettin KOÇ* | ***HALL AVANOS / SALON AVANOS*** |
| 09:10-09:30 | **BORLANMIŞ SOĞUK İŞ TAKIM ÇELİĞİNİN MİKRO-ABRASYON AŞINMA DAVRANIŞI**<br>M Sabri GÖK, Yılmaz KÜÇÜK, Mecit ÖGE, Gökhan SAĞLAM, Ali GÜNEN |
| 09:30-09:50 | **KONVERTER ALTINDAKİ SIVI ÇELİK POTALARI İÇİN OTOMATİK KÜLÇE ALÜMİNYUM BESLEME SİSTEMİ TASARIMI**<br>Mesut TUTAL, Ahmet KAYRAK, Yılmaz ERBİL, Serdar GÜZEL |
| 09:50-10:10 | **PARALEL FLANŞLI ÖZEL KESİTLİ PROFİL TASARIMI VE SİMÜLASYON DESTEKLİ ÜRETİMİ**<br>İlter KİLERCİ, Serhat ARALAR , Muhammed ZENGİN , Ceren GÖDE |
| 10:10-10:30 | **SÜBAP ÇELİĞİ YÜZEYİNDE TRD YÖNTEMİYLE ÜRETİLEN KARIŞIK NİTRÜR ESASLI KAPLAMALARIN MİKROYAPI ÖZELLİKLERİ**<br>Serkan Islak, Cihan Özorak |
| 10:30-10:50 | **ALÜMİNLERİN TİTREŞİMLİ SÜRTÜNME DAVRANIŞLARININ PARAMETRİK MODELLEMESİ**<br>A.G. URAL, J. DENAPE, J.-Y. PARİS |
| ***Session Chairman /Oturum Başkanı:****Prof.Dr.Fatma KARİPCİN* | ***HALL LODGE / SALON LODGE*** |
| 09:10-09:30 | **EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER FROM A POROUS PLATE WITH TRANSPIRATION COOLING**<br>Mustafa Kilic |
| 09:30-09:50 | **EFFECT OF DOLOMITE POWDER ON TECHNOLOGICAL PROPERTIES OF WPC AND NEAT POLYPROPYLENE**<br>Ferhat Özdemir, Nadir Ayrilmis and Fatih Mengeloğlu |
| 09:50-10:10 | **DETERMINETION OF RADIATION INTERACTION PROPERTIES OF SOME SUPER ALLOYS AND FERROALLOYS**<br>Mehmet Büyükyıldız, Murat Kurudirek |
| 10:10-10:30 | **ENERGY SAVING BY INSULATION IN A FOOD FACTORY STEAM GENERATING PLANT**<br>Mehmet Ali TOPÇU and Aydın RÜŞEN |

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| 10:30-10:50 | **A NOVEL METHOD TO DETERMINE INTERLAMINAR FRACTURE CHARACTERISTICS OF LAMINATED COMPOSITES**<br>Fatih Darıcık, İsmail Can Yılmaz |
| ***Session Chairman /Oturum Başkanı:****Yrd.Doç.Dr.İhsan KIRIK* | ***HALL IHLARA / SALON IHLARA*** |
| 09:10-09:30 | **WEAR PROPERTIES OF HOT PRESSED CU-TIC COMPOSITES**<br>Serkan ISLAK |
| 09:30-09:50 | **TOZ BOYUTUNUN OKSİT İÇERİKLİ SERAMİK KAPLAMANIN ADEZİV AŞINMA DAVRANIŞINA ETKİSİ**<br>Yılmaz KÜÇÜK, M. Sabri GÖK, Mecit ÖGE |
| 09:50-10:10 | **NEVŞEHİR DÖŞEME TAŞLARI ATIKLARININ YER KAROSU BÜNYELERİNDE KULLANIMI**<br>Zahide BAYER ÖZTÜRK, Mertcan ERİŞ |
| 10:10-10:30 | **KİL BAĞLAYICI KULLANARAK ÜRETİLEN VERMİKULİT ESASLI TUĞLALARIN ÖZELLİKLERİNİN İNCELENMESİ**<br>Serkan DAL, Mücahit SÜTÇÜ, M. Sabri GÖK, Osman GENÇEL |
| 10:30-10:50 | **SINTERING CHARACTERISTICS AND GRAIN GROWTH BEHAVIOR OF $SiO_2$-DOPED $BaTiO_3$ CERAMICS**<br>Kerim Emre ÖKSÜZ, Şaduman ŞEN and Uğur ŞEN |
| 10:50-11:10 | ***COFFE BREAK / ÇAY-KAHVE ARASI*** |
| ***SESSION 5 / OTURUM 5*** | |
| ***Session Chairman /Oturum Başkanı:****Yrd. Doç. Dr. Volkan KIRMACI* | ***HALL URGUP 1 / SALON ÜRGÜP 1*** |
| 11:10-11:30 | **ASSESMENT OF THE NITRATION PROCESS PARAMETERS TO IMPROVE THE WEAR RESISTANCE OF DIN 1.2714 QUALITY HOT WORK TOOL STEEL**<br>Muhammed AYAZ, Ogulcan AVCIOGLU, Samet AKSOY, Hayrettin AHLATCI, Mustafa ACARER, Yavuz SUN, Yunus TUREN, İsmail Hakkı KARA, Caner AKTASOGLU , Umit Kagan OZTURK |
| 11:30-11:50 | **INVESTIGATION OF WEAR PROPERTIES OF BORIDED X32CrMoV33 STEEL**<br>Melih OZCATAL, Ibrahim GUNES |
| 11:50-12:10 | **FABRICATION OF POROUS $SI_3N_4$ BASED CERAMICS IN AIR ATMOSPHERE**<br>Ayse KALEMTAS and Okan BILGIC |
| 12:10-12:30 | **Co BAZLI ŞEKİL HATIRLAMALI ALAŞIMLARIN MORFOLOJİSİNİN KOMPOZİSYONA BAĞLILIĞI**<br>Murat Eskil, Kemal Aldaş, Zeynep Aylin Şahan |
| ***Session Chairman /Oturum Başkanı:****Prof.Dr.Bilge DEMİR* | ***HALL URGUP 2 / SALON ÜRGÜP 2*** |
| 11:10-11:30 | **APS YÖNTEMİ İLE BİRİKTİRİLMİŞ $Cr_2O_3$ KAPLAMANIN YÜKSEK SICAKLIK AŞINMA DAVRANIŞI**<br>Yılmaz KÜÇÜK, M. Sabri GÖK,. Mecit ÖGE |
| 11:30-11:50 | **KUTU BORLAMA YÖNTEMİYLE BORLANMIŞ PASLANMAZ ÇELİKLERİN YÜZEY ÖZELLİKLERİNİN İNCELENMESİ**<br>Yusuf KAYALI, Şükrü TAKTAK, Sinan ULU |
| 11:50-12:10 | **MELT SPİNNİNG YÖNTEMİYLE NdFeB MANYETİK TOZLARIN ÜRETİMİ VE KARAKTERİZASYONU**<br>Sultan ÖZTÜRK, Kürşat İCİN, Hülya Kaftelen, Bülent ÖZTÜRK, Uğur Topal, Abdurrahim Metoğlu |
| 12:10-12:30 | **KÜLTİVATÖR YAYLARINDA YORULMA DAVRANIŞLARININ İNCELENMESİ**<br>Hamit Adin, Raşit Koray Ergün |
| ***Session Chairman /Oturum Başkanı:****Prof.Dr.Cevdet GÖLOĞLU* | ***HALL ZELVE / SALON ZELVE*** |
| 11:10-11:30 | **MELT SPINNING YÖNTEMİYLE AA6060 ALÜMİNYUM ALAŞIMI ŞERİT ÜRETİMİ VE İNCELENMESİ**<br>Sultan ÖZTÜRK, Sefa Emre SÜNBÜL, Kürşat İCİN, Bülent ÖZTÜRK Murat EROĞLU |
| 11:30-11:50 | **MADEN VE GALERİ TAHKİMAT SİSTEMLERİNDE KULLANILAN MİKROALAŞIMLI SICAK HADDELENMİŞ PROFİLİN BÜKME PROSES TASARIMI VE SİMÜLASYONU**<br>Aytaç BAŞSÜLLÜ, Serhat ARALAR, İlter KİLERCİ, Osman ÇULHA |
| 11:50-12:10 | **MİG-MAG KAYNAK TEKNİĞİ İLE BİRLEŞTİRİLEN FARKLI BOR İÇERİĞİNE SAHİP TRIP ÇELİĞİNİN MİKROYAPISININ İNCELENMESİ**<br>Cemal ÇARBOĞA, Bülent KURT, Serkan DAL |
| 12:10-12:30 | **MAKASLI KALDIRMA SİSTEMİ TASARIMI VE SONLU ELEMANLAR YÖNTEMİYLE ANALİZİ**<br>Cengiz Görkem DENGİZ, Mahmut Can ŞENEL, Kemal YILDIZLI, Erdem KOÇ |
| ***Session Chairman /Oturum Başkanı:****Doç.Dr.Mehmet KAYA* | ***HALL AVANOS / SALON AVANOS*** |
| 11:10-11:30 | **GRAFEN KATKILI BAKIR ESASLI ELEKTRİK MOTOR FIRÇALARI**<br>Hüseyin İpek, Hamdullah ÇUVALCI, Aykut ÇANAKÇI |
| 11:30-11:50 | **Al-Cd FERRİTLERİN DİELEKTRİK ÖZELLİKLERİNİN İNCELENMESİ**<br>T. Şaşmaz Kuru, E. Şentürk |

# SINTERING CHARACTERISTICS AND GRAIN GROWTH BEHAVIOR OF $SiO_2$-DOPED $BaTiO_3$ CERAMICS

Kerim Emre ÖKSÜZ[a] , Şaduman ŞEN[b] and Uğur ŞEN[b]
[a] Cumhuriyet University, Department of Metallurgical & Materials Engineering, 58140, Sivas, Turkey.
[b] Sakarya University, Department of Metallurgical & Materials Engineering, 54187, Sakarya, Turkey.
E-mail: kerimemreoksuz@gmail.com, ugursen@sakarya.edu.tr, sdmnsen@sakarya.edu.tr.

## Abstract

In this study, grain growth kinetics and sintering behavior of $SiO_2$ doped barium titanate based ceramic materials were investigated depending on sintering temperature and time. In this process, $SiO_2$-*doped* $BaTiO_3$ ceramic powder substitution was prepared by solid state mixed oxide technique. X-ray diffraction analysis showed that the main phases formed in the sintered samples are $BaTiO_3$. Atomic force microscope (AFM) images were used for examinations of the grain structure and size of the sintered samples. Grain growth kinetic equation $G^n=K.t.exp(-Q/RT)$ was used for determining the activation energy of the $SiO_2$-*doped* $BaTiO_3$ ceramic materials. It was suggested that $SiO_2$ is important to barium titanate ceramics not only for sintering, but also for modifying their properties.

**Keywords:** Barium titanate, grain growth, kinetic, activation energy, sintering.

## 1. Introduction

Barium titanate-based ceramics are widely applied in high-dielectric-constant ceramic capacitors, positive temperature coefficient of resistivity (PTCR) thermistors and lead-free ceramic piezoelectric devices. As barium titanate is usually sintered at temperatures around 1300 °C, numerous researches have been devoted to the sintering of barium titanate-based ceramics to lower the sintering temperature and to optimize the properties of the components and devices as well [1] and [2]. Usually, the microstructure of such ceramics is a result of liquid phase sintering. The required liquid phase is formed by a reaction between a suitable additive and the $BaTiO_3$ matrix powder [3] Some glass-based flux additions are especially effective for these purposes and they are generally adopted as sintering aids for barium titanate-based ceramic components and devices, among which $SiO_2$ is one of the most important components. It was reported that there exists a ternary eutectic in the system of BaO–$TiO_2$–$SiO_2$ and $SiO_2$ addition promotes grain growth and lowers the sintering temperature of $BaTiO_3$ ceramics through liquid phase sintering [4], though the nature of the working liquid phase is still under investigation. On the other hand, Wang et al. have pointed out that glass-based flux additions not only result in liquid phases at high temperatures, some of their components can also be incorporated into $BaTiO_3$ lattice and modify the dielectric properties, such as the Curie temperature and the sharpness of the ferroelectric transition as usual dopants [5]. In addition to other authors, Drofenik [6] reported on the defect structure and grain growth in donor-doped $BaTiO_3$ both with $SiO_2$ and with $TiO_2$ as an additive. Drofenik showed that the oxygen partial pressure has a pronounced influence on the grain growth and related effects in donor-doped $BaTiO_3$. Shimanskij et al. investigated the grain growth in donor-doped barium titanate below the temperature of liquid phase formation [7]. The origin of the grain growth anomaly in donor-doped $BaTiO_3$ was explained by Drofenik introducing an additional thermodynamic term, which is associated with energetic demands due to the release of oxygen during incorporation of the critical amount of the dopant [8]. In a previous paper, we have studied the influence of $B_2O_3$ on the crystallographic structure, phase transition, grain size, microstructure and physical properties of barium titanate and barium titanium zirconate ceramics when it is introduced as a dopant rather than a sintering aid and some interesting results were reported [9]. In this paper, a similar study has been conducted on $SiO_2$ and grain growth kinetic equation $G^n=K.t.exp(-Q/RT)$ was used for determining the activation energy of the $SiO_2$-*doped* $BaTiO_3$ ceramic materials. Our result shows that $SiO_2$ can have obvious influences on the grain size, microstructure and physical properties of barium titanate ceramics and attention should be paid to $SiO_2$ not only as a sintering aid but also as a dopant for barium titanate ceramics.

## 2. Experimental Procedure

$SiO_2$-*doped* $BaTiO_3$ ceramics used in this study were prepared by the conventional ceramic processing techniques. Commercially available powders of $BaCO_3$ (Alfa Aesar A13195), $SiO_2$ and $TiO_2$ (GPR 30446, 98% purity) were used as starting materials. $BaCO_3$, $TiO_2$ and $SiO_2$ powders were mixed as to be 0.7/1.0/0.3 molar ratio. The stoichiometrically weighed amounts of these powders were milled by ball milling technique in isopropyl alcohol using $ZrO_2$ balls at 200 cycles/min for 20h and then dried in a pyrex pan. The dried powder was calcined at 1000 °C for 2 h. The calcined powders were crushed using the planetary ball mill for a short duration and, compacted by cold uniaxial pressing at 300 MPa and then sintered at 1175°C, 1200°C and 1225°C for 1-4 h. (at a ramp of 5°C/min.). Then, the samples were polished and thermally etched for metallographic examination. The density of the sintered samples was measured using the Archimedes' method. The samples were characterized by AFM and XRD analysis. The AFM images were obtained using a Quesant AFM (Ambios Technology, Santa Cruz, CA) at 3 Hz scanning rates. Grain size measurements were carried out on the AFM images of the etched samples using the Eq. 1:

$$G = 1.56 \cdot \overline{L} \quad (1)$$

where, *G* is the average grain size, $\overline{L}$ is the average grain-boundary intercept length of four random lines on each micrographs of each sample [10-12]. AFM Quesant software is helpful to determine the grain-boundary intercept. In the grain size measurement, minimum five images were used as the determination of average grain dimensions. XRD analysis were realized using by a Rigaku D/MAX-2200/PC type difractometer (Tokyo, Japan) with Cu-Kα radiation, which has a wavelength of 1.5418 Å over a 2θ range of 10°–90° with 0.033° increments per second to analyze phases present in the produced samples.

## 3. Result and Discussion

### 3.1 Phase Analysis

The X-ray diffraction patterns of $SiO_2$-*doped* $BaTiO_3$ ceramics sintered at 1225°C were given in Fig. 2. In all cases, the diffractograms have predominantly registered the phase of barium titanate-($BaTiO_3$), matched for every sample (ICSD card no. 79-2265). X-ray diffraction patterns of $SiO_2$ doped $BaO$-$TiO_2$ powders showed that the peaks correspond to $BaTiO_3$ crystalline phase, confirming that $SiO_2$ is effectively incorporated into the $BaTiO_3$ matrix. The figure proves that the barium titanate ceramics are successfully produced without noticeable undesirable phases.

### 3.2 Microstructure and Grain Size Measurement

Fig. 3. shows atomic force microscope (AFM) images of $SiO_2$-*doped* $BaTiO_3$ ceramics obtained after sintering at 1225°C for 1-4 h. As shown from this figure that the AFM images give some information about grain sizes and structures of the ceramics. AFM micrograph presents good microstructure with 3D for the measurement of the grains produced. $SiO_2$-*doped* $BaTiO_3$ ceramics produced via powder metallurgy technique have an almost homogeneous equiaxed grain structures. As shown in this figure, grain size increases with increasing sintering temperature due to the liquid/glassy phase formation by $SiO_2$. Fig. 1. shows the grain size of $SiO_2$-doped $BaTiO_3$ ceramics depending on sintering time and temperature.
The grain growth kinetics can be calculated using the simplified kinetic equation;

$$G^n = K.t.\exp\left(-\frac{Q}{RT}\right) \quad (2)$$

where G is the average grain size, *n* is the kinetic grain growth exponent value, K is a constant, t is the time, Q is the apparent activation energy, R is the universal gas constant and T is the absolute temperature [11–15]. The kinetic grain growth exponent value (*n*) in the Eq. (2) can be determined from the following equation;

$$n.\log(G) = \log(t) + \left(\log(k) - 0.434\left(\frac{Q}{RT}\right)\right) \quad (3)$$

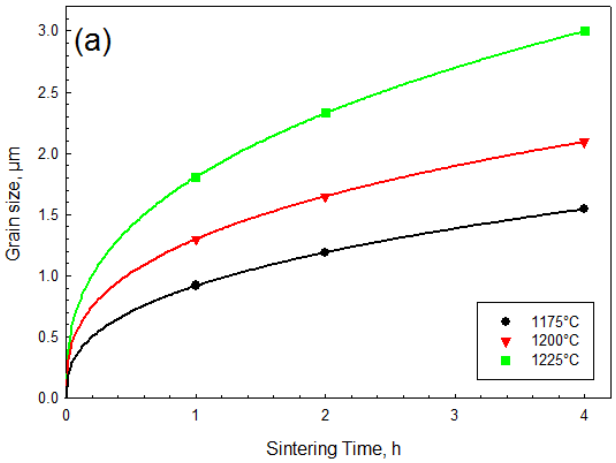



Figure 1. shows the grain size of the the $SiO_2$-doped $BaTiO_3$ ceramics depending on sintering time and temperature.

From the slope of the log (G) versus log t line, which is 1/n, the grain growth kinetic exponent is readily determined. Fig. 4. illustrates the isothermal grain growth of the $SiO_2$-*doped* $BaTiO_3$ ceramics sintered at 1175°C, 1200°C, 1225°C for 4h. The average grain size increases with increasing heat treatment temperature and time, as expected from Eq. (3). Kinetic exponent calculated from the slopes of these plots were determined for the sintering temperatures of 1175°C, 1200°C, 1225°C are found to be 2.67, 2.92 and 2.74, respectively. The apparent activation energy (Q) for the grain growth process can be calculated from the gradient of the Arrhenius plot (Eq. (2)) of log ($G^n$/t) versus (1/T). This plot was constructed for the studied system as shown in Fig. 4. The apparent activation energy is 192.6 kJ/mol. The relative density and open porosity of the sintered ceramics were determined using the Archimedes' water displacement method, as specified by European Standard EN 99 (ISO 10545-3, 1991) [16]. Relative density, and open porosity of $SiO_2$-*doped* $BaTiO_3$ ceramics, results are shown in Fig. 5. The relative density of sintered ceramics increases with increasing of the sintering temperature (from 1175°C to 1225°C) and the sintering time (from 1h to 4h). For all ceramics, open porosity decreases with sintering time and with increasing temperature.

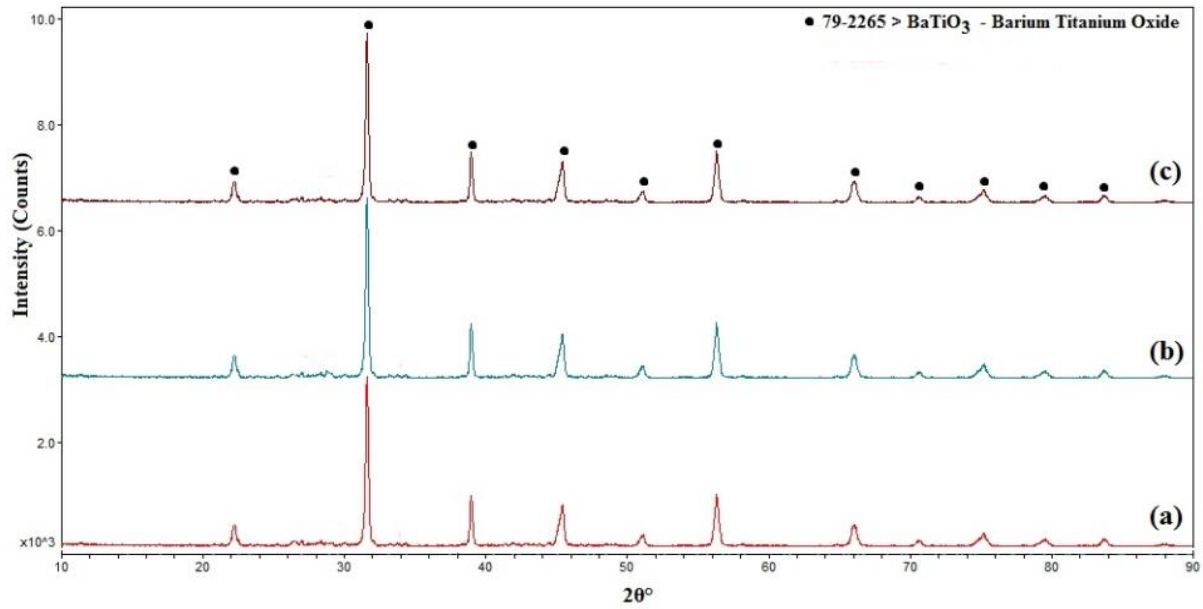



Figure 2. X-ray diffraction patterns of $SiO_2$-*doped* $BaTiO_3$ sintered at 1225°C. (a) 1h, (b) 2h, (c) 4h.

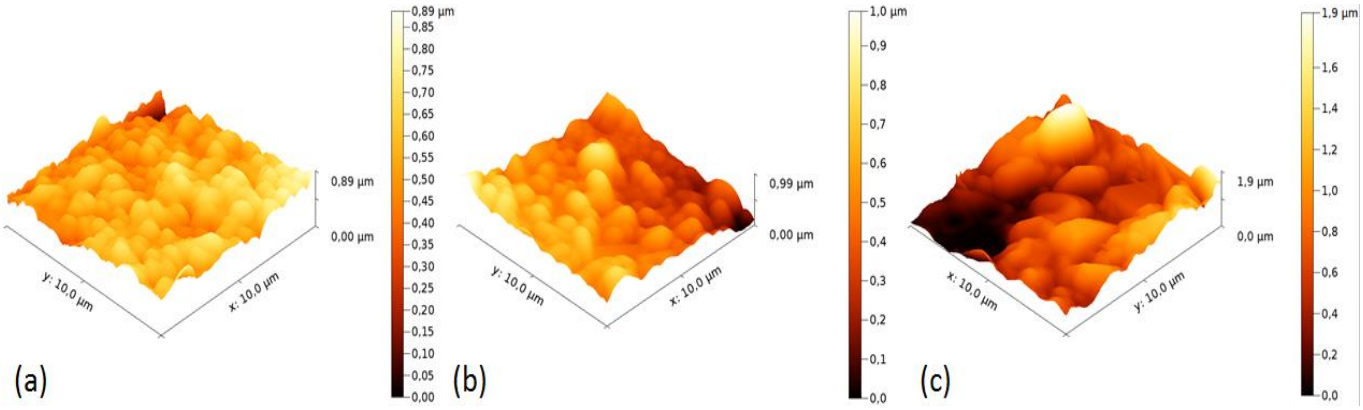



Figure 3. Atomic force microscope of $SiO_2$-*doped* $BaTiO_3$ sintered at a) 1175°C, b) 1200°C, c) 1225°C for 4h.

Choi and Kim [15] studied the sintering behavior of barium titanate ceramics with $SiO_2$ addition and reported eutectic temperature as 1250°C due to the liquid phase sintering. They explained that *rapid grain growth takes place in* the final stage of the *liquid phase sintering and* large pores are formed in grain boundaries as a result of coalescence phenomenon.

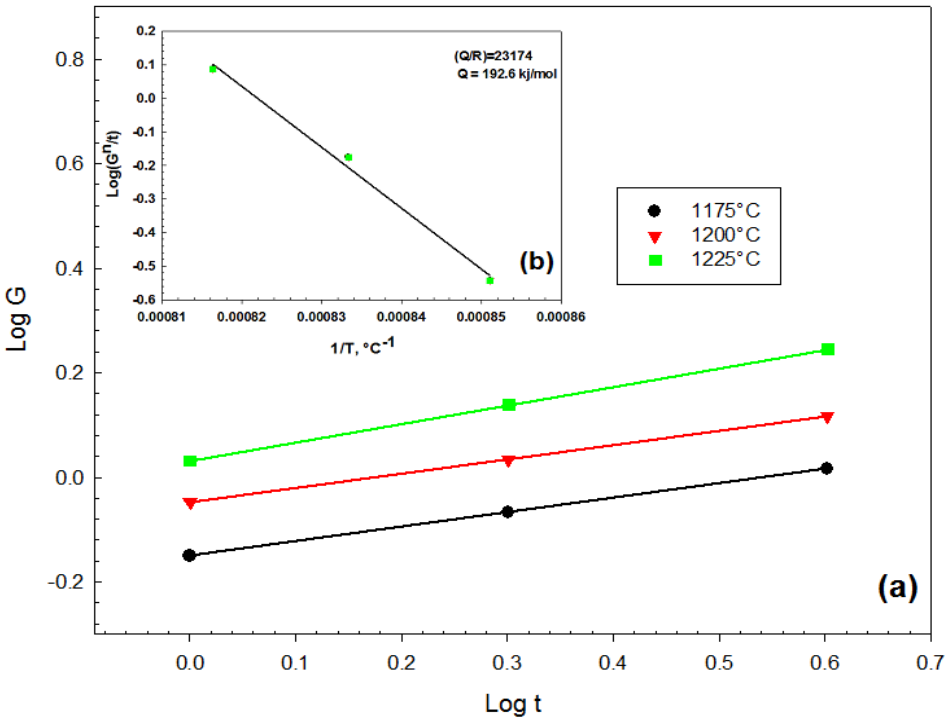



Figure 4. (a) Isothermal grain growth and (b) the Arrhenius plot for the grain growth of $SiO_2$-*doped* $BaTiO_3$ at different sintering temperatures.

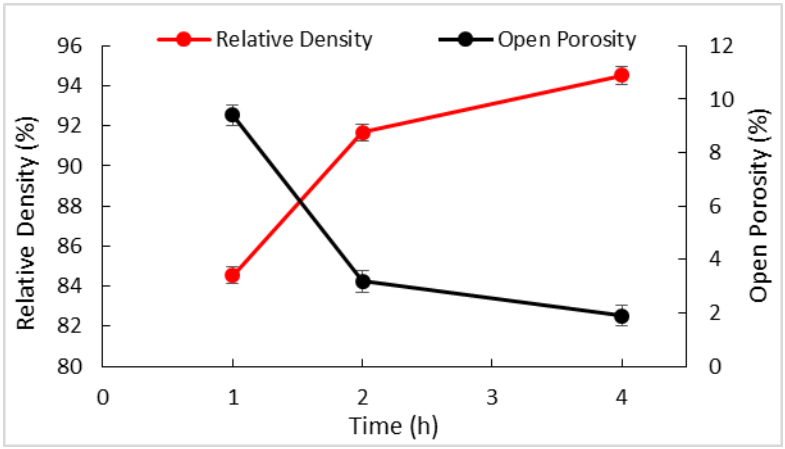



Figure 5. Relative density and open porosity vs. sintering time of $SiO_2$-*doped* $BaTiO_3$ ceramics after sintering at 1225°C.

## Conclusions

In the present study, the effect of sintering temperature and time on the grain size, microstructural evolution, density-open porosity, and grain growth kinetics of $SiO_2$-*doped* $BaTiO_3$ ceramics were investigated. AFM images showed that the grains formed in the $SiO_2$-*doped* $BaTiO_3$ ceramics are homogeneous equiaxed grain structure. The grain sizes of the ceramics are changing between 0.9 and 2.98 µm depending on the process parameters. the higher the sintering temperature and the longer the sintering time, the coarser the grain size became. X-ray diffraction analysis results showed that single-phase perovskite structure for $SiO_2$ doped $BaTiO_3$ based ceramics took place at room temperature. The grain growth kinetics exponent values (n) are changing between 2.67, 2.92 and 2.74 depending on sintering temperature and time. An increase in the sintering temperature causes to increase of n values and crystallinity degree of the ceramics. The grain growth activation energy of the $SiO_2$-*doped* $BaTiO_3$ ceramic was calculated as 192.6 kJ/mol. For all ceramics, it is observed that the relative density increases with increasing sintering temperature and time.

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